# A Study of Some Morphological and Anatomical Aspects of *Anthurium andreanum* Lind.

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# A STUDY OF SOME MORPHOLOGICAL AND ANATOMICAL ASPECTS OF
## *Anthurium andreanum* Lind.

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## ABSTRACT

*Anthurium andreanum* Lind. is a perennial, herbaceous monocotyledon in the family Araceae with cordate leaves and flowers. The commercial "flower" is an inflorescence consisting of conspicuous bract (spathe) and protruding rachis (spadix), on which minute perfect flowers are borne helically. The flowers are protogynous; the stigma is receptive before the pollen is shed. Anatomically, the spathe has a uniseriate upper and lower epidermis, one or two layers of hypodermal cells, and 10 to 12 layers of spongy parenchyma cells. Anthocyanin is localized in the hypodermal cells. The leaf blade is similar to the spathe, except for two layers of palisade parenchyma cells immediately below the upper epidermis. Venation is netted. Chloroplasts are dispersed throughout the mesophyll but are more concentrated in the palisade cells. The peduncle, petiole, and stem are typically monocotyledonous in structure. Epidermal cells cover the cortex, a layer of sclerified parenchyma cells, and the ground tissue. Vascular bundles are dispersed throughout the ground tissue. Roots are cylindrical, fleshy, epiphytic, and adventitious. The epidermis is developed as a velamen. Raphide and druse crystals are found throughout the plant. Above-ground parts have a thick, waxy cuticle.

Keywords: Araceae, monocotyledon, plant structure.

## INTRODUCTION

In an anatomical study of *Anthurium violaceum* Schott var. *leucocarpum*, Campbell (2) gave a comprehensive description of the flower, the fertilization process, and embryo development in the seeds and pointed out that because aroid flowers are markedly protogynous, self-pollination is impossible (1).

Christensen (3) noted that *A. scherzerianum* Schott and *A. andreanum* Linden have juvenile phases followed by generative phases. The difference is in the axillary buds. In the juvenile stage, leaves have short sheaths with a vegetative bud in the axil, while in the generative stage an inflorescence bud is situated in the axil of the leaves. Instead of a leaf sheath, the sheath covering the axil and upper part of the petiole base protecting the inflorescence bud is composed of stipules.

Kamemoto and Nakasone (6) described the flower of *A. andreanum* as hermaphroditic with a two-carpelled ovary and four anthers. They also discussed the sequence of leaf and inflorescence production. The inflorescence emerges about a month after leaves appear and precedes the next new leaf by a

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few weeks. This sequence of emergence is maintained throughout growth, although the intervals between leaf emergence vary, depending upon environmental conditions.

Watson and Shirakawa (8) related flower development of *A. andreanum* to the inflorescence shelf life. More mature inflorescence had a longer shelf life.

Information on the anatomy of *A. andreanum* is limited, yet knowledge of the nature and function of the plant is the basis for solving production and handling problems. This study examines the external and internal anatomy and morphology of the anthurium plant.

## MATERIALS AND METHODS

Whole-plant observation as well as light and scanning electron microscope observations were used to characterize *Anthurium* both morphologically and anatomically. Cultivar 'Ozaki Red' was used in the study.

### Gross Morphology

Fresh, mature *Anthurium* plants were dissected and the gross morphology of root, stem, leaf, and flower was studied and recorded.

### Anatomical Studies

*Light microscope.* Standard paraffin procedures by Jensen (5) were followed. Tissue sections (8 $\mu$m) were stained with safranin and counterstained with fast green. The tissues were studied with a light microscope (Olympus) and the data recorded.

*Scanning electron microscope (SEM).* Procedures by Rasmussen and Hooper (7) were followed. The tissue was coated with approximately 20 nm of carbon followed by 20 to 40 nm of Au-Pd (60 percent and 40 percent) by vacuum evaporation. The coated tissue was studied in the SEM (Advanced Metal Research Model 900) at 21 kV accelerating potential.

## RESULTS AND DISCUSSION

### Gross Morphology

A typical commercial *A. andreanum* plant is shown in Figure 1. It is a low-growing perennial, herbaceous plant that thrives best under 60 to 80 percent shade at temperatures of 18° to 24°C and a relative humidity of 60 to 80 percent. The leaves are simple, cordate with entire margins, and at maturity are usually 20 × 35 cm. The leaf blades are attached to a cylindrical petiole that basally forms a fused sheath around the stem. Stipules are borne at the sheath and stem junction on mature leaves.

The short, thick stem has nodes approximately 1 cm apart; depending on the cultivar and the environment, however, long, thin stems with internodes as long as 15 cm may be found. For example, 'Ozaki Red' has short, stocky internodes, whereas 'Nitta Orange' has long, thin internodes. Increased shade promotes longer internodes, while high light produces shorter internodes regardless of cultivar. The leaves have a spiral arrangement on the stem.

A vegetative, adventitious, lateral bud is formed at alternate nodes, opposite each leaf junction. The vegetative buds are helically arranged and opposite the leaves.

Flower buds are borne in each leaf axil. A mature inflorescence has a conspicuous bract (spathe) joined to the base of a cylindrical spike or rachis (spadix) and attached to a long peduncle. The botanical flowers are minute and perfect. There are approximately 300 flowers arranged helically on the spadix. The fruits are small, globose, yellow berries closely arranged on the spadix. There are two seeds per berry that germinate immediately after sowing. The first flower is produced about 18 months after germination.

The roots are adventitous and originate from the stem nodes. They are cylindrical, thick, and fleshy and emerge from below the

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vegetative bud or the leaf. The primary roots branch and form secondary and tertiary roots. Root hairs are present 40 to 50 mm from the root apex.

Two scale leaves or bud scales occur at each node: one between the flower peduncle and the stem, the other covering the lateral vegetative bud. The former is a bud scale that earlier covered the apical meristem of the plant.

This study supports the work of Christensen (3), who reported that A. andreanum, when propagated by seed, goes through a juvenile phase followed by a generative phase. The difference in phase is evident at the base of the petiole sheaths with a vegetative bud in the axil. As the plant matures a flower bud forms at the axil of the leaf with no petiole sheath. Instead the stipules from the sheath cover the axil and upper part of the petiole base, thus protecting the flower bud.
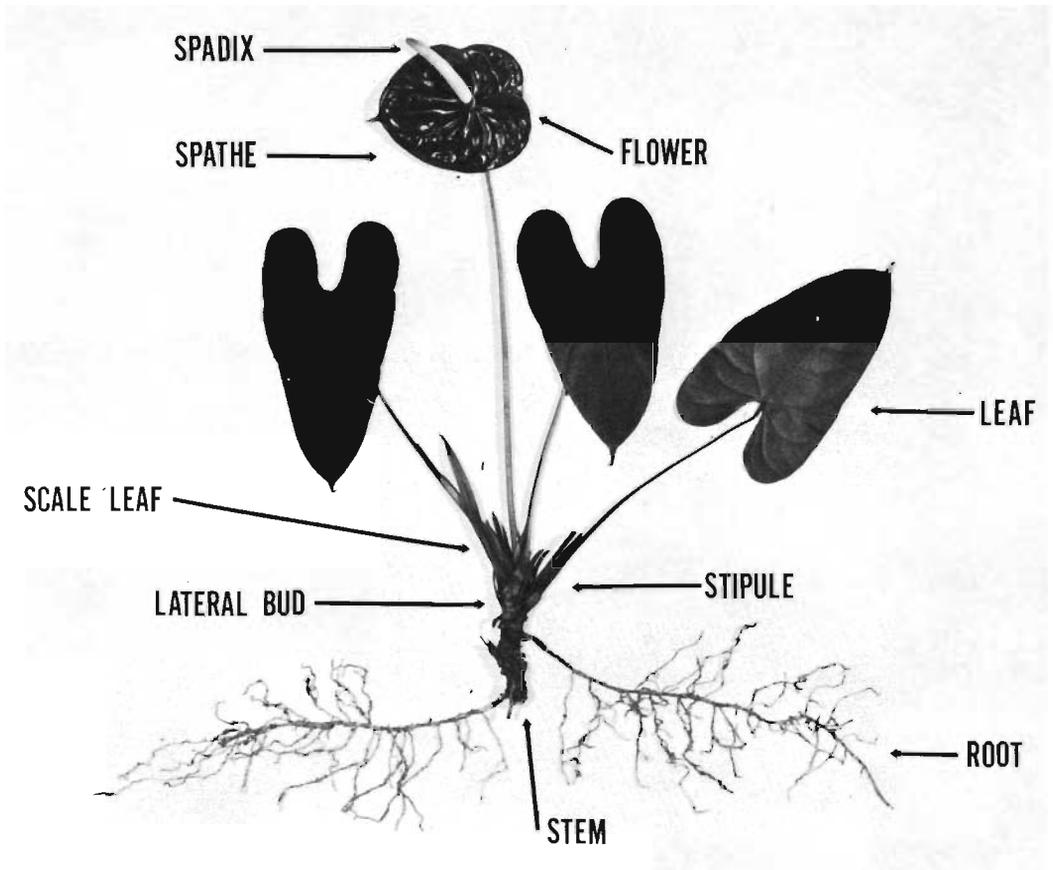


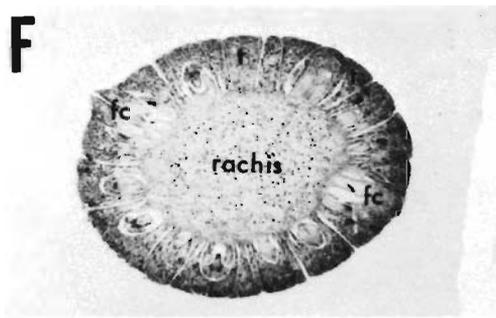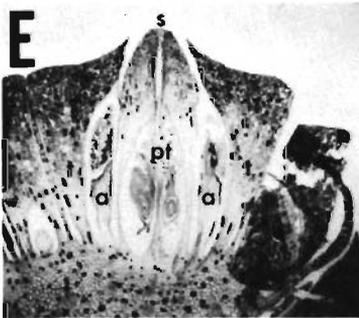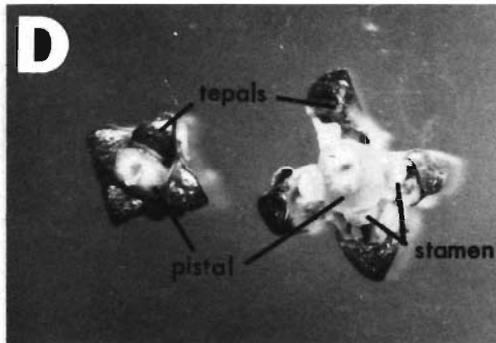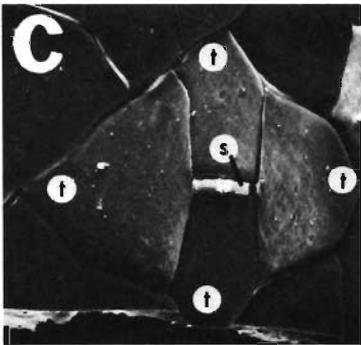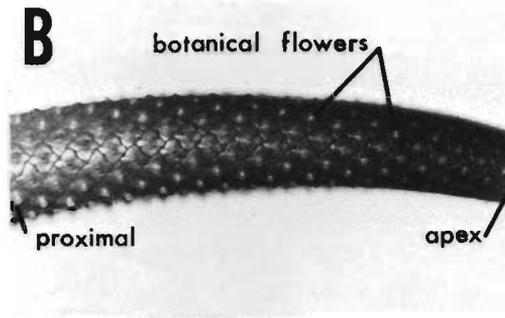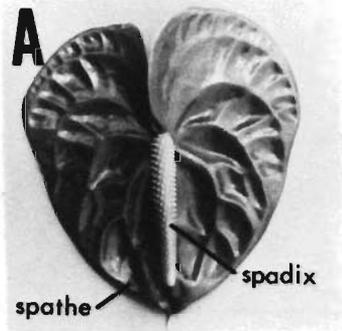Figure 1. Typical *Anthurium andreanum* plant.

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Figure 2. Anatomy and morphology of anthurium inflorescence. A = anthurium inflorescence consisting of spathe and spadix; B = spadix with flowers; C = surface morphology of flower, SEM photomicrograph, ×30; D = flower, ×10; E = longitudinal section of flower, ×100; F = cross section of spadix, ×10. t = tepal, s = stigma, a = anther, pt = pistil, fc = floral cavity.

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## Inflorescence and Flowers

The inflorescence of *A. andreanum* (Figure 2A) consists of three parts: the peduncle or stalk, the bract or spathe, and the spadix. The flowers are perfect, small, and borne on the spadix on a central rachis, Figure 2B. The proximal flowers mature first with development progressing toward the apex. The surface view of the flower is shown in Figures 2C and 2D. Four fleshy perianth segments (tepals) envelop four stamens and a fleshy compound gynoecium. Each stamen is located opposite a tepal and pressed firmly against the gynoecium. A longitudinal section of the flower and cross section of the spadix are shown in Figures 2E and 2F. At the periphery of the spadix the tepals form the floral cavity and are attached to the central rachis. The floral cavity contains the stamens and carpel. Anatomically the tepals have an outer epidermal cell layer over ground parenchyma cells. Vascular bundles are interspersed throughout the ground cells. Many tepal cells contain druse and raphide crystals, more than any other cells in the anthurium plant. These crystals are found scattered throughout the plant, even in some epidermal cells.

The stamen has a flat filament with a single vascular bundle in the center, which traverses the entire filament and ends blindly in the connective tissue located between the two anthers. The anther is bilobed with each lobe containing two locules (Figures 3A and 3B). The outermost layer is a one-celled epidermis. The subepidermal layer is the endothecium; the innermost layer, the tapetum (not shown in the photograph), is frequently composed of multinucleate cells. The tissue between the endothecium and the tapetum is often crushed during development of the pollen sac. The developing sac is evident in the locules. Mature pollen is observed as a white powdery mass on the spadix (Figures 3C and 3D).

The ovary (Figure 4) is hypogynous, as the tepals and androecium arise from the receptacle below the gynoecium (Figure 2E). It is a syncarpous gynoecium with two fused carpels. Each carpel has a single locule with single ovule; each berry has two ovules (Figure 4B). Within the ovary, the wall and the locule cavities can be identified (Figures 4B and 4C). Placentation is axile. The single sessile style has two stigmas that elongate into papillae, featherlike short hairs (Figure 4D). The stigma has glandular secretory tissue, and the stigmatic fluid provides a suitable medium for pollen germination.

As the flower develops, the tip of the cylindrical, subconic ovary protrudes through an opening at the tip junction of the tepals, and the expanded style exposes the stigmatic surface (Figure 4E). The stigma is receptive to pollination when a sticky, translucent stigmatic fluid is secreted at the tip of each flower on the spadix (Figures 4F and 4G). Pollination can be accomplished by collecting pollen on a soft brush and applying it to a receptive stigma on the spadix. Natural pollination by insects also takes place.

Each fertilized ovary enlarges, forming a single berry with one or two seeds (Figure 4H) that mature in approximately six months.

The *A. andreanum* flower is protogynous. After the stigmas protrude through the tepals they become receptive, dehydrate, and shrink. The anthers then emerge and shed their pollen above the tepals. The time lapse between stigma receptivity and dehiscence is about a week.

The spathe of *Anthurium,* usually 12 × 14 cm, is a modified leaf or bract. It is usually cordate but may assume other shapes. It is usually simple, but some cultivars have a compound spathe. The spathe, in various colors, is the product for which *A. andreanum* is grown commercially. The prominent veins of the spathe originate at the spadix-spathe junction and diverge in

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an arcuate manner following the shape of the spathe. Then they converge and fuse at the spathe apex. The major veins are interconnected by smaller transverse veins. The thickness of the spathe is approximately 400 to 600 $\mu$m.

The upper and lower surfaces of the spathe have a thick cuticle and, except for a slightly lighter pigmentation in the lower epidermis, there is little anatomical difference between these surfaces. There are six to seven stomata per mm$^2$ on the lower surface with fewer on the upper surface (Figure 5A).

In cross section (Figure 5B) just below the upper cuticle layer of the spathe is a single cell layer of epidermal cells. These cells are broad, rhomboid, and usually pentagonal. Beneath the epidermis is a single or double layer of isodiametric hypodermal cells. Similarly, the lower epidermis has a single cell layer composed of more typically tabloid cells. Between the upper and lower hypodermal layers are 10 to 12 irregularly arranged layers of spongy parenchyma cells. Vascular bundles are dispersed at uniform intervals throughout the spathe. Microscopic observation of fresh samples indicates that the an-
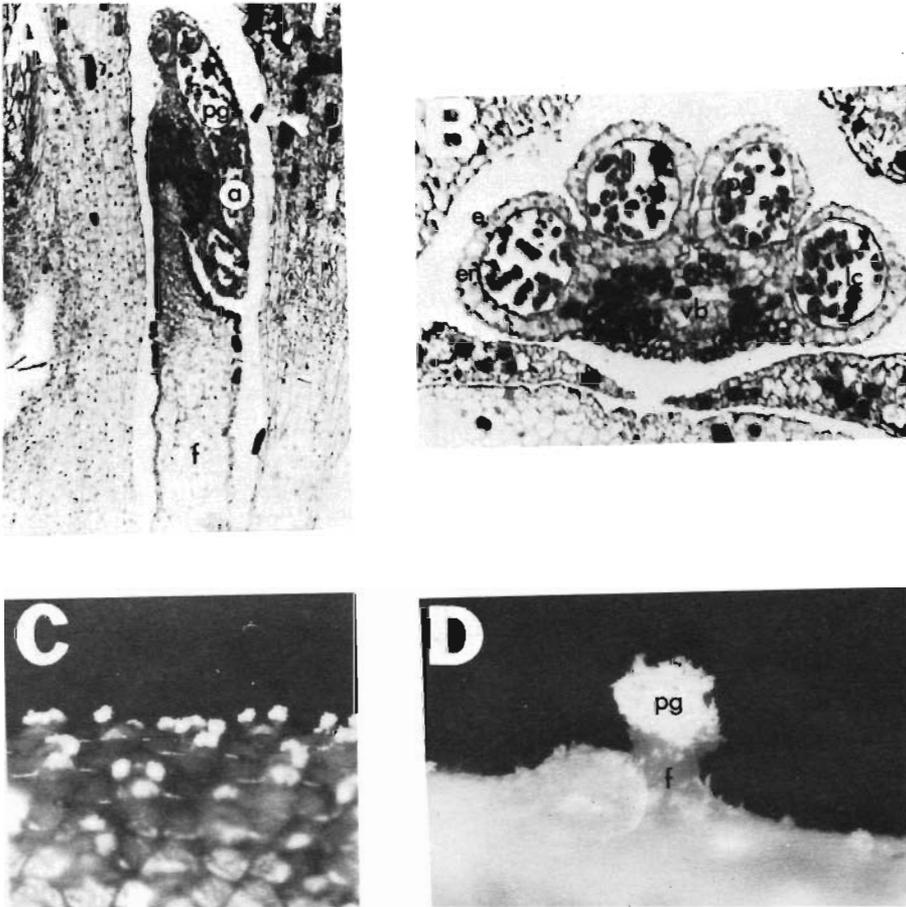


Figure 3. Stamens of anthurium. A = longitudinal section of stamen, $\times$100; B = cross section of anther, $\times$100; C = pollen shed on spadix, $\times$10; D = anther with pollen, $\times$50. pg = pollen grains, a = anther, f = filament, e = epidermal layer, en = endothecium, lc = pollen sac, vb = vascular bundle.
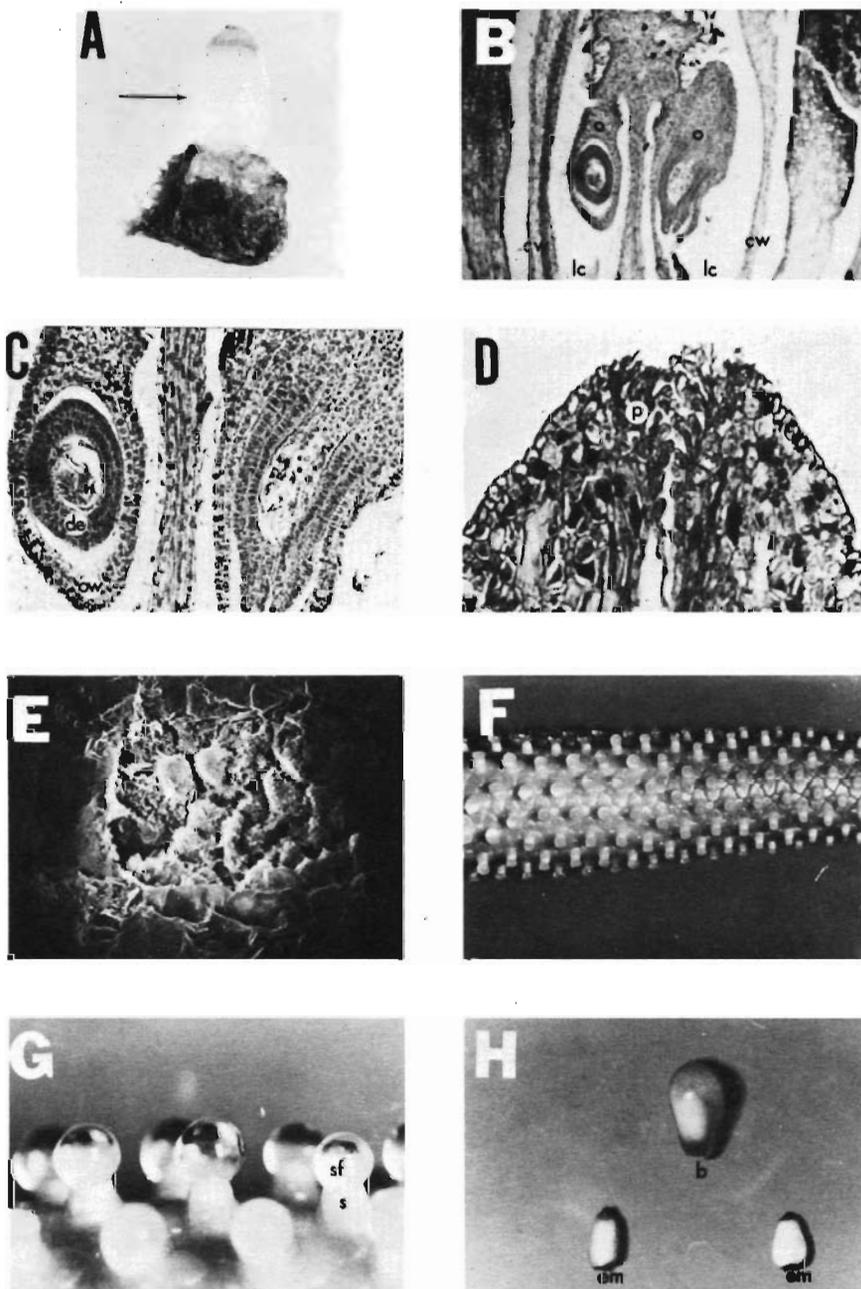
Figure 4. Gynoecium of anthurium. A = gynoecium (arrow), ×10; B = longitudinal section of pistil, ×10; C = longitudinal section of ovary, ×125; D = longitudinal section of stigma apex, ×150; E = top view of stigmatic area, SEM ×600; F = spadix with receptive stigmas, ×10; G = receptive stigmas with stigmatic fluid, ×50; H = berry and two seeds, ×1. o = ovule, cw = carpel wall, lc = locule cavity, de = developing embryo, ow = ovary wall, p = papillate hairs of stigma, sf = stigmatic fluid, s = stigma, b = berry, em = embryo.
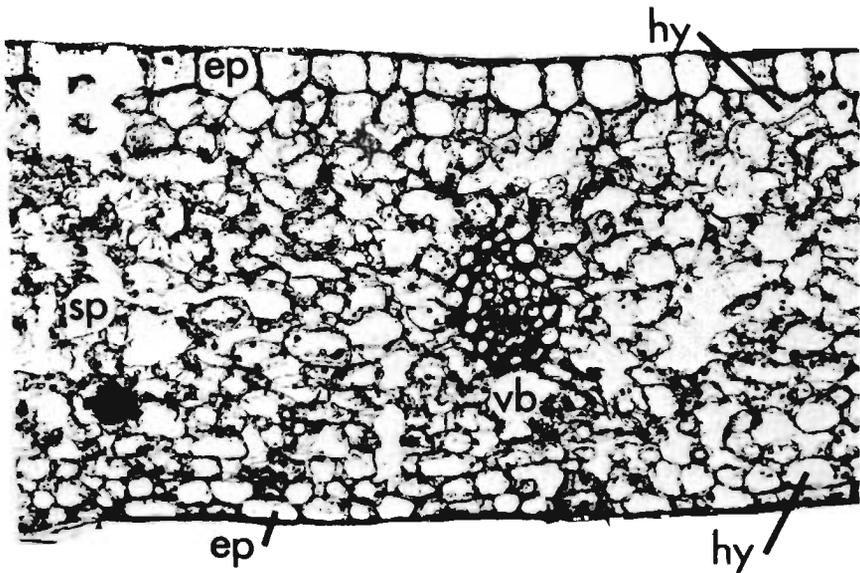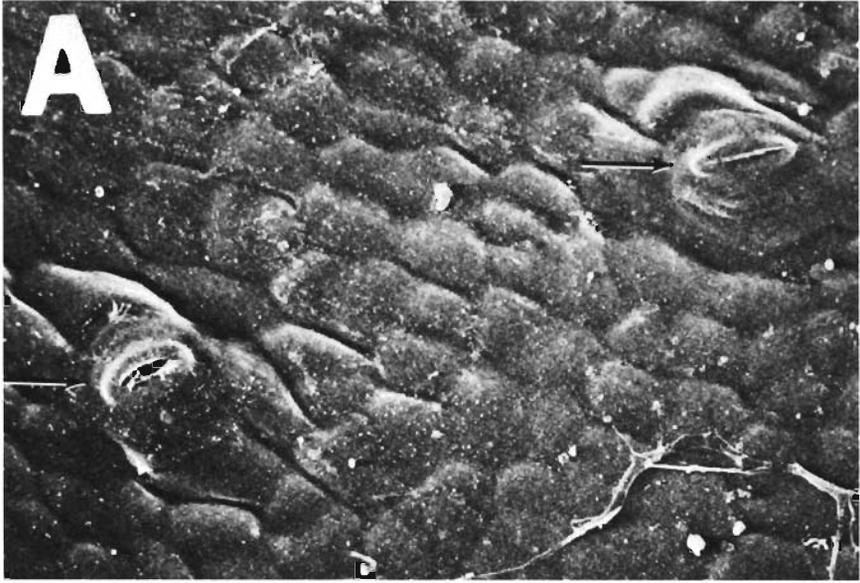
Figure 5. Spathe of anthurium. A = stomata on upper surface of spathe (arrows), ×2000; B = cross section of spathe, ×100. ep = epidermis, hy = hypodermis, sp = spongy parenchyma tissue, vb = vascular bundle.

thocyanin pigments of the spathe are concentrated in the hypodermal cells. The epidermal and spongy parenchyma cells are devoid of anthocyanin.

The mature flower stem or peduncle is smooth, cylindrical, and approximately 40 to 60 cm in length and 0.5 cm in diameter. The outer surface of the epidermis is covered with a thick, waxy cuticle with some stomata.

In cross section the peduncle is topographically similar to the stem. A single layer of epidermal cells is subtended by the cortex. A layer of sclerified parenchyma cells separates the cortex and the ground parenchyma cells. The vascular bundles are dispersed among the ground parenchyma cells throughout the stem. The vascular bundles are enclosed in a parenchymatous bundle. The pith is continuous and composed of ground parenchyma cells.

## Leaf

The leaf blade is simple, green, and cordate with entire margins; it is approximately 20 cm wide, 35 cm long, and 400 to 500 $\mu$m thick. The main veins emerge from the base of the leaf at the petiole-blade junction. The veins extend in arcuate fashion out to the leaf margins. The major veins are interconnected by smaller veins in a netted pattern. Stomatal pores are only on the lower surface. There are approximately 30 to 40 stomates per mm² with random distribution.

The blade has both upper and lower one-cell-thick epidermal layers. The upper epidermal cells are relatively thicker and isodiametric in shape, while the lower epidermal cells are more tabloid. Between the epidermal layers is the mesophyll, which has one or two layers of compact palisade parenchyma cells. The palisade cells are adjacent only to the upper epidermal layer of the leaf blade. The leaves are therefore dorsiventral or bifacial with a dark green upper surface and lighter green lower surface.

Collateral vascular bundles of various sizes with adaxially located xylem and ensheathed in fibers are dispersed throughout the mesophyll. Chloroplasts are present in all mesophyll cells but are more concentrated in the palisade cells.

The petiole is cylindrical, smooth, and usually 25 to 35 cm long. The base of the petiole forms a sheath around the stem. Stipules at the basal end of the sheath cover the flower bud in its early stages. The epidermal surface is smooth and covered with a thick, waxy cuticle. A few stomata are dispersed irregularly on the stem surface.

The anatomical structure of the petiole is similar to the peduncle described earlier. The epidermis is composed of a single layer of cells with subtending cortex consisting of several layers of parenchyma cells. A layer of sclerified parenchyma cells separates the cortex and the ground parenchyma tissue, and each is surrounded by a sclerenchymous sheath. The pith is continuous and composed of isodiametric cells.

## Root

The roots are adventitious, arising from the stem. Two roots emerge just below the axillary bud or leaf at a node. Adventitious roots branch readily to form a fibrous root system. The spongy, fleshy roots are cylindrical, 0.5 to 1.0 mm in diameter. They are aerial and have the capacity of attaching themselves to various surfaces. Root hairs are apparent about 40 to 50 mm proximal to the root cap in the zone of maturation.

The root cap protects the meristem, which is located just below the root cap. The cells are thin walled and cubical in shape with large nuclei and dense cytoplasm. Immediately adjacent is the zone of elongation where differentiation begins and maturation continues. These cells have large vacuoles, less dense cytoplasm, and slightly thicker walls.
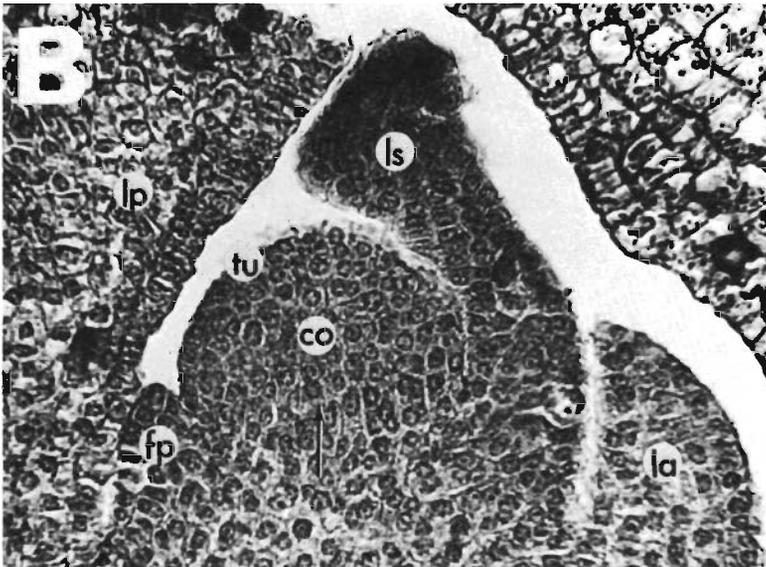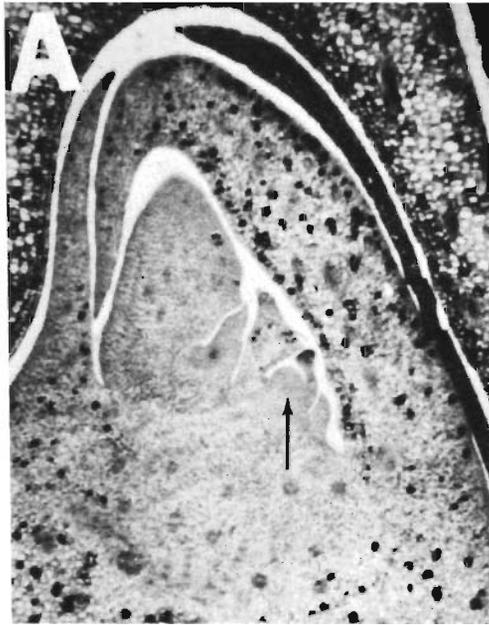
Figure 6. Terminal bud of anthurium. A = longitudinal section of apical meristem (arrow), ×150; B = enlarged view of meristematic region (arrow), ×300. lp = leaf primordium, fp = inflorescence primordium, ls = leaf scale primordium, la = lateral shoot primordium, tu = tunica, co = corpus.

The root in cross section shows multiple layers of epidermal cells. The multiseriate tissue, or multiple-layered epidermis called "velamen," is commonly found in Araceae. This tissue consists of compact, nonliving cells, often with secondary wall thickening. The function of the velamen is absorption, but studies by Dycus and Knudson(4) on orchids indicated that its principal role is mechanical protection and water conservation. The cortex is located adjacent to the velamen with layers of large, thin-walled parenchyma cells. The innermost cortical layer has smaller cells, which form the endodermis. Xylem, phloem, and parenchyma cells compose the stele.

## Stem

The stem is cylindrical, fibrous, and at maturity is approximately 2 cm in diameter. Leaves are arranged helically. The helical pattern may develop either clockwise or counterclockwise. The nodes are paired as the internodes alternate between "short" and "long" internodes. One node gives rise to the lateral vegetative bud, while the other produces the leaf. Morphologically, in most plants the occurrence of buds without leaves is rare. More than likely, a leaf primordium is initiated with or before the bud but never develops fully. That this is the case in anthuriums has not yet been proved. The short internode is about 0.015 cm long, while the long internode varies from 1 to 5 cm. In common usage, the short internode is often referred to as the "node" and the long internode as the "internode."

Stem growth on a mature plant is about 5 cm per year, but since it is a perennial, stems up to 4 m long are common. Lateral shoots develop at the lower nodes, and eventually these produce additional lateral shoots. In three to four years the original stem may have 10 or 12 additional branching stems.

The topography of the stem in cross section is similar to that of the peduncle and the petiole discussed earlier. The stem has one layer of cells forming the epidermis. The epidermis surrounds a cortical layer that is much thicker in width than in the peduncle or petiole. Vascular bundles enclosed in sheaths of sclerenchyma tissue are dispersed in ground tissues. The pith is continuous and consists of thick-walled parenchyma cells.

The vegetative apical meristem (Figure 6) is offset from the center of the shoot. This off-center position is caused by the helical characteristic of the stem in which the apical meristem is displaced laterally by the developing leaf primordium. The primordium occurs at the periphery of the apex, possessing undifferentiated embryonic cells.

At the meristematic apex are two layers of tunica cells (Figure 6B), which divide perpendicularly to the surface of the meristem (anticlinal division). Directly beneath the tunica is the corpus, where cell division occurs in several planes (anticlinal and periclinal). The corpus adds bulk to the apical portion of the shoot by increasing in volume, whereas the tunica maintains its continuity over the enlarging body by surface growth.

## SUMMARY

A study of the morphology and anatomy of *A. andreanum* was conducted. It is a perennial, herbaceous monocotyledon in the family Araceae and therefore possesses typical monocotyledonous anatomical structures. Of particular significance among its characteristics are these: (1) a juvenile phase of seedlings and a reproductive phase at maturity. The juvenile phase produces lateral shoots in the leaf axils, whereas the reproductive phase produces inflorescences in similar positions. The lateral shoot is opposite the leaf attachment; (2) the inflorescence has a cordate spathe and protruding spadix,

whereas the botanical flowers are minute, perfect, and borne on the spadix; (3) the roots have a velamen; and (4) the above-ground parts of the plant are covered with a thick, waxy cuticle.

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