

MORPHOLOGY AND ANATOMY OF TROPICAL FLOWERS

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Summary

The Angiospermae may reproduce sexually by flower. The flower can be considered as a shoot with modified leaves. Flower presents pedicel, receptacle, perianth which consists of sepals (calyx) and petals (corolla), androecium and gynoecium. Androecium is formed by stamens being each constituted by anther, connective and filament. Gynoecium is composed by one or more carpels which form the ovary, style and stigma. Flowers may present nectaries which secrete nectar (sugar and other substances). Flowers may occur on inflorescences which may be racemes or monopodial and cymes

or sympodial types. The perianth usually has uniseriate epidermis and homogeneous mesophyll. The young anther wall presents epidermis, endothecium, middle layers and tapetum. Ovary has simple epidermis, parenchymatic mesophyll and vascular bundles. The style presents epidermis, parenchyma, vascular bundle and transmitting tissue. The upper surface of the stigma may be covered with papillae or trichomes which produce a slimy substance (stigmatic secretion). The ovule consists of the nucellus and one (unitegmic ovule) or two integuments (bitegmic ovule); it has a stalk termed funiculus, a small opening, the micropyle, and the embryo sac which is formed by seven cells (three antipodal cells, one central cell, two synergids and egg cell). A mature pollen grain is surrounded by exine and intine, and contains two (vegetative and generative cell) or three cells (vegetative cell and two spermatid cells). The pollen grains are transported to the stigma by abiotic or biotic agents (pollination). The pollen grain germinates on the stigma of the flower and originates a pollen tube which carries within it the two spermatid cells and penetrates into the embryo sac through the micropyle of the ovule. In the process of fecundation result the embryo and the endosperm. The ovule integuments, endosperm and embryo constitute the seed. The ovary wall originates the pericarp of the fruit.

1. Introduction

The sexual reproduction of Angiospermae (Magnoliophyta) occurs in the flower. The Angiospermae flower (Figure 1A,B) presents leaves with different forms, sizes, colors, number and disposition. The flower can be considered as a shoot with modified leaves. The floral leaves are arranged in stem axis in rosette; they are densely crowded upon one another. Some floral leaves are sterile and other fertile ones. The sterile leaves form the perianth that aid in the reproduction process, exercising the protection function of the reproductive organs, the dispersion of fruits or serving as attraction agents for pollination, as insects, birds and bats. The fertile leaves form male and female reproduction organs, the androecium and gynoecium.

Flowers with androecium and gynoecium are termed bisexual or perfect. If either is lacking, the flower is unisexual or imperfect. It may be termed either staminate, if only the androecium is present, or carpellate, if only the gynoecium is present. The plant is monoecious, if both staminate and carpellate flowers are borne on a single individual; in dioecious species, staminate and carpellate flowers are borne on separate individual plants. When both bisexual and unisexual flowers (staminate and/or carpellate) occur on the same plant, the species is termed polygamous.

In Brazil occurs a native plant named *Araucaria angustifolia* (pinheiro-do-paraná), Araucariaceae that belongs to the Gymnospermae group. This species possesses flowers very different from Angiospermae. The male and female flowers are inserted on the axis (strobilus, cone or inflorescence) (Figure 1F,G) and they occur in different trees, characterizing the species as dioecious one. Each male flower is constituted by a coriaceous scale that produces anthers with pollen. The female flower is represented by an open scale that exposes a single ovule.

There are two theories to explain the origin of the flower. The first is denominated euanthium theory and it establishes that a hermaphrodite flower is originated from a

uniaxial sporophyll-bearing structure with micro- (male) and macrosporophylls (female). The other theory is the pseudanthium one which maintains that the angiosperm flower may have originated in a complex system of axes, similar to an inflorescence with numerous male and female flowers without perianths.

In the nature there are very colored flowers that call the attention and the human's feeling. On the other hand, there are also inconspicuous and uncolored flowers as in Poaceae (Gramineae), that pass unnoticed by the human glance. Independently of the beauty or of the feeling that they promote, the flowers are indispensable in the perpetuation and in the genetic variability of the plant species. In these plants, with or without an external agent's help, the fertilization process occurs in the flower that results in the formation of fruits/seeds (Figure 1C,D,E) and seeds (Figure 1H,I).

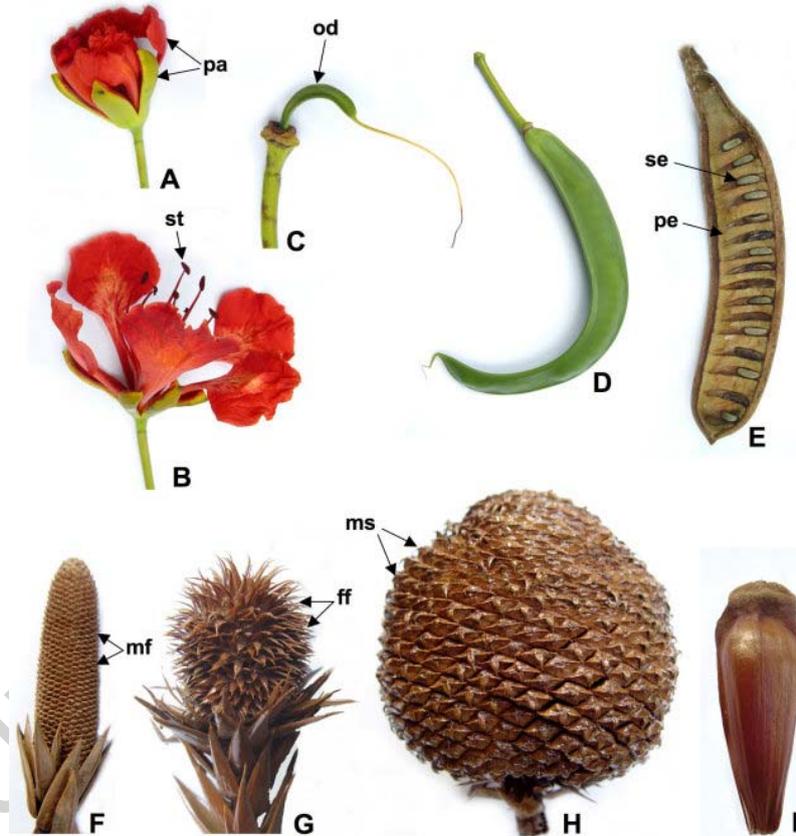


Figure 1 - Flowers/fruits of Angiospermae and flowers/seeds of Gymnospermae. Figs. A-E- Flowers(A, B), Young fruits (C,D) and mature fruit (E) of *Delonix regia*. Figs. F-I - Male and female inflorescences(strobili) (F,G), strobilus with seeds (H) and the seed (I) of *Araucaria angustifolia*(ff=female flowers; mf=male flowers; ms=megasporophylls (carpels) with seed; od=ovary in developing; pa =perianth; pe=pericarp; se=seed; st=stamen)

2. Flower Morphology and Anatomy

2. 1. Hypsophylls

Hypsophylls are bracts and bracteoses. Bracts are leaves that are attached in the base of

the flowers or inflorescences. The bracts differ of the nomophylls (normal leaves) for shape, size, consistence or color. With reference to the color, the bracts can be green or present another color, usually attractive. Inflorescences of Araceae species have bracts termed spathes with red, white or green color. *Bougainvillea spectabilis* (primavera or trêsmarias), Nyctaginaceae (Figure 2A) shows red or white bracts.

The bracteoses are green and reduced leaves that occur in lateral axes of the inflorescences or in floral pedicel.

Bract anatomy – When the bracts are green they present a structure similar to a homogeneous mesophyll and veins. Colored bracts and with delicate texture differ of the foliage leaves and the division of the mesophyll into palisade and spongy parenchyma is usually lacking.

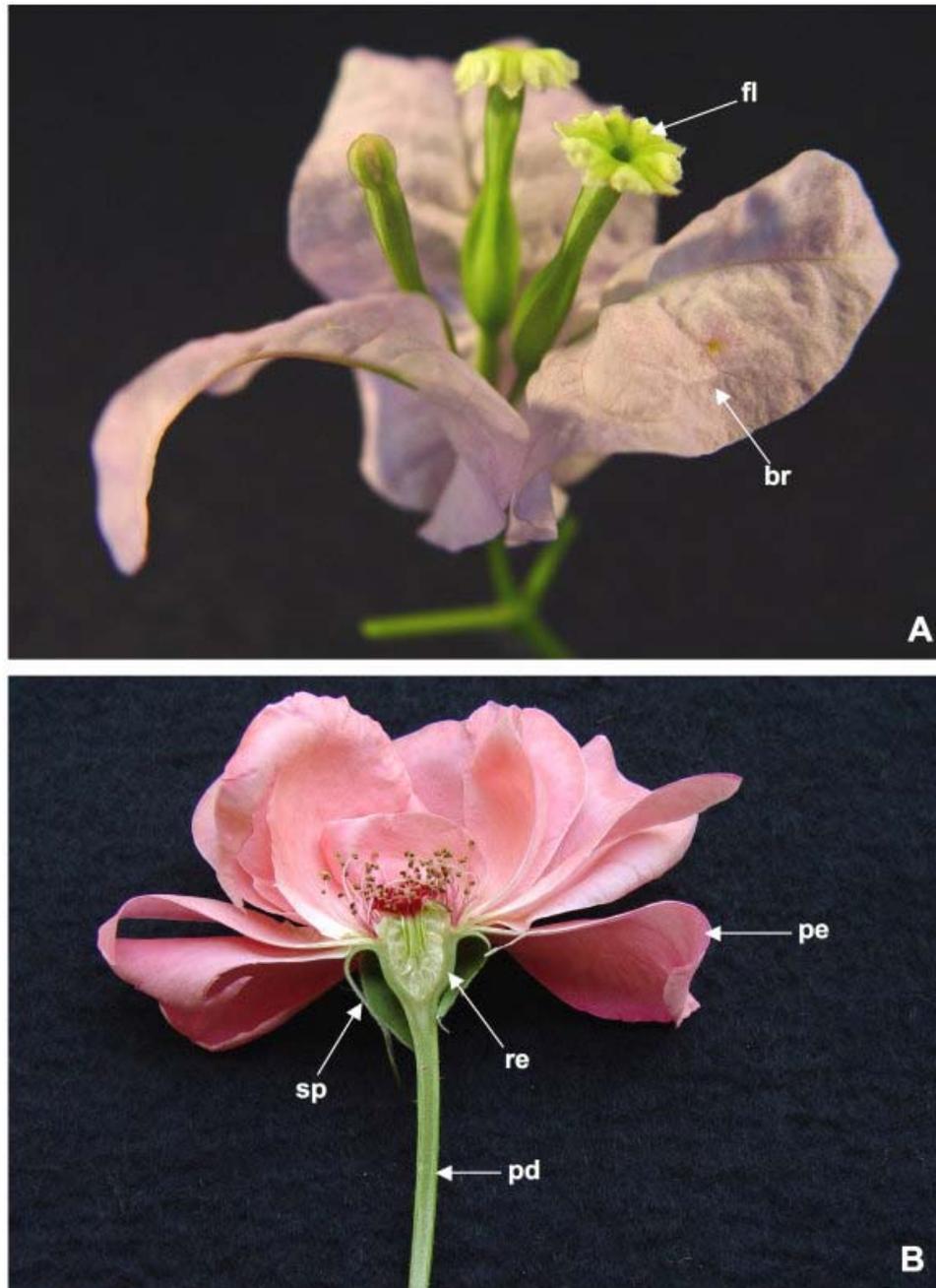


Figure 2 - Morphology of the flower. Fig. A- Monochlamydeous flowers of *Bougainvillea spectabilis* with bracts. fig. B - Dichlamydeous flower of *Rosa* (br = bract; fl = flower; pd = pedicel; pe = petal; re= receptacle ; sp = sepal)

In Piperaceae the bracts have heterogeneous mesophyll in *Ottonia martiana* (Figure 3E,H) and homogeneous one in *Peperomia dahlstedtii* (Figure 3D,G) and *Piper gaudichaudianum* (Figure 3F,I).

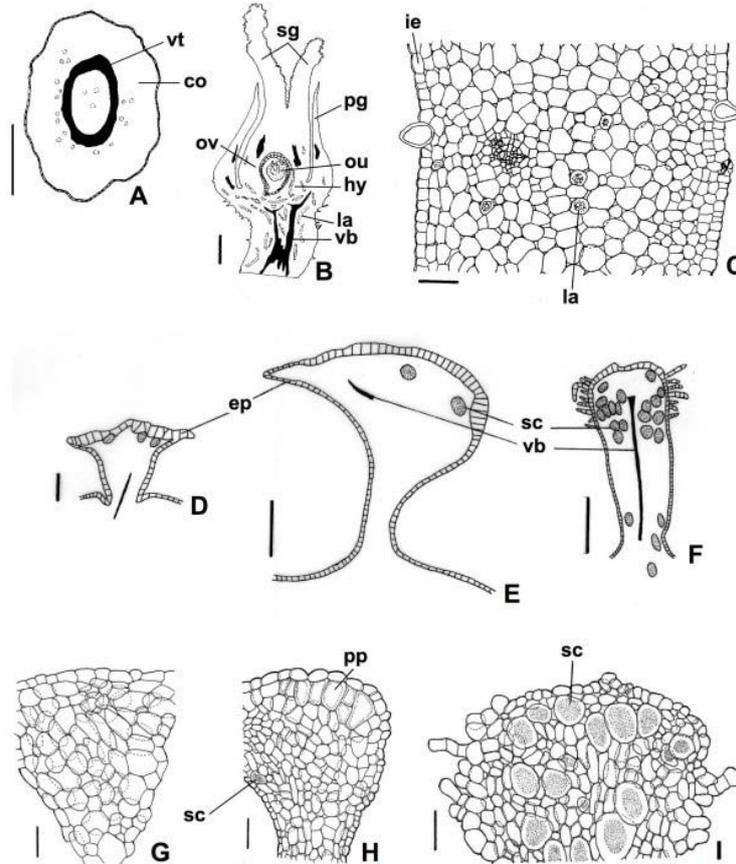


Figure 3 - Structure of the pedicel, perigone and bract. Fig. A - Pedicel of *Cordia trichotoma* in cross section. Figs. B, C - Flower diagram and anatomical detail of the perigone of *Sorocea bomplandii* in longitudinal sections. (co = cortex; ep = epidermis; hy = hypanthium; ie = inner epidermis; la = laticifer; ou = ovule; ov = ovary; pg = perigone; pp = palisade parenchyma; sc = secretory cell; sg = stigma; vb = vascular bundle; vt = vascular tissue). Bars = 50 mm (C, G, I), 100 mm (D, H), 200 mm (E, F), 0.5 mm (A, B)

2.2. Floral Pedicel

The part of the axis that represents the internode terminated by the flower is termed pedicel (Figure 2B). The pedicel can be short or long and it has variable thickness. When the flower has no peduncle it is termed sessile. Flower sessile is observed in *Zea mays* (corn) spike.

Pedicel anatomy – The pedicel has stem structure (Figure 3A). It presents the same tissues that the stem in primary and secondary growth. In Dicotyledoneae flowers there are epidermis, collenchymatous and parenchymatous cortex, central cylinder with collateral vascular bundles and parenchymatous pith. The pedicel can form peridermis and secondary xylem and phloem. Monocotyledoneae flowers consist of epidermis and vascular bundles that are scattered throughout the ground tissue of the pedicel.

2.3. Floral Receptacle

The distal end of the pedicel is swollen to various extents and this portion is termed the

floral receptacle (Figure 2B). The floral organs are attached to the receptacle.

For example, in *Tabebuia chrysotricha* (ipê-amarelo), Bignoniaceae and *Cabrlea canjerana* (canjerana), Meliaceae the receptacle is a little expanded. On the other hand, in *Nectandra megapotamica* (canelinha-amarela), Lauraceae and in *Rosa* (rose), Rosaceae (Figure 2B) the receptacle is quite developed.

2.4. Anthophylls

The flower consists of anthophylls that are the sterile and fertile leaves. The sterile leaves are the sepals and petals and they constitute the perianth (Figures 1A,B; 2B, 4A). The fertile leaves are the carpels (gynoecium) and the stamens (androecium).

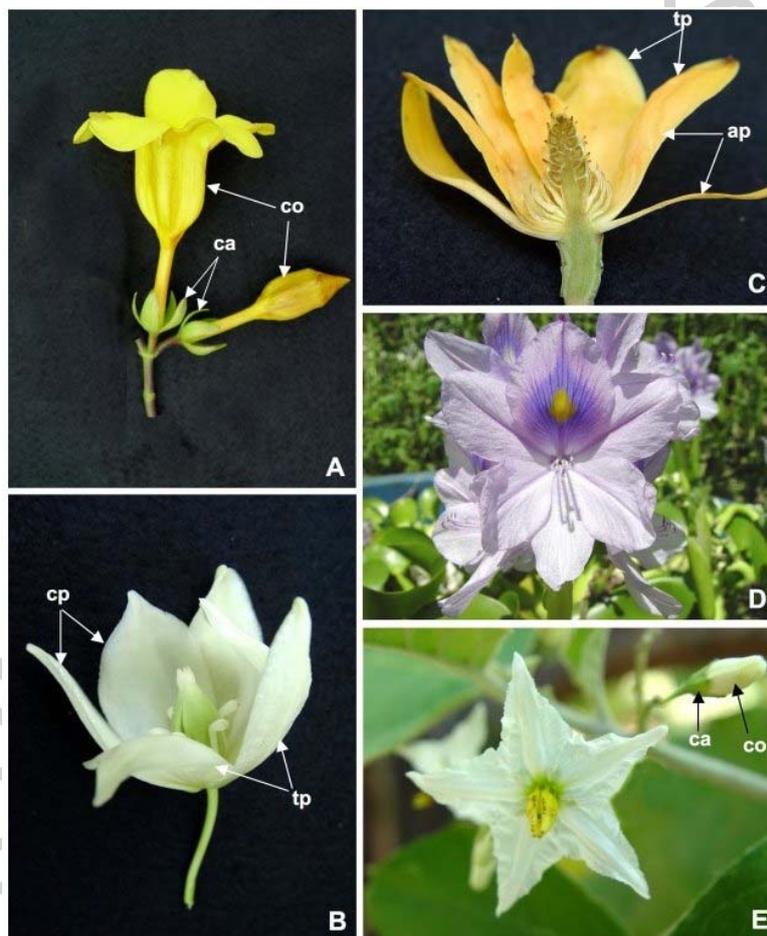


Figure 4 - Morphology of the flower. Fig. A- Heterochlamydeous and dichlamydeous flower of *Allamanda cathartica*. Fig. B - homochlamydeous flower of *Yucca*. Fig. C- Homochlamydeous flower of *Magnolia champaca* in longitudinal section. Fig D - Zigomorphic flower of *Eichhornia crassipes*. Fig. E - Actinomorphic flower of *Solanum paniculatum*. (ap= acyclic perigone; ca= calyx; co= corolla; cp= cyclic perigone; tp= tepal)

The anthophylls may be arranged in the axis of the flower, forming circles or floral whorls; in this case the flower is denominated cyclic (Figure 4A,B). When the

anthophylls are arranged in the axis forming a continuous helix, the flower is acyclic (Figure 4C). The flower with helical arrangement is seen as primitive. Acyclic flower may be observed in *Magnolia champaca* (magnolia-amarela), Magnoliaceae (Figure 4C) and *Victoria amazonica* (victória-régia), Nymphaeaceae. Cyclic flowers occur in most of the plant species.

2.5. Perianth/Perigone

The perianth consists of sepals and petals. The sepals are outermost leaves which together constitute the calyx (Figures 1B, 4A) which is usually green. On the inside of the sepals is the corolla (Figures 1B, 4A) which consists of usually colored petals. The calyx and corolla may be lacking, one of them or all perianth. Flowers without perianth occur in Poaceae (Gramineae) and some Euphorbiaceae species.

The perianth is termed perigone (Figure 4B,C) when the sterile whorls are similar. The perigone leaves are denominated tepals, as may be seen in *Yucca*, Agavaceae (Figure 4B). The *Sorocea bonplandii* (sorócea), Moraceae, a forest plant, shows perigone (Figure 3B). The monocotyledons flowers, in general, also possess tepals.

Flowers with similar calyx and corolla (principally color) are termed homochlamydeous (flowers with perigone) (Figure 4B) and they are seen in *Ocotea puberula* (canela-babosa ou canela-guaicá) and *Nectandra megapotamica* (canelinha-amarela), both species belonging to the Lauraceae family. Heterochlamydeous flowers have different calyx and corolla, with green sepals and colored petals, which may be observed, for example, in *Allamanda cathartica* (alamanda-amarela), Apocynaceae (Figure 4A) and *Spathodea nilotica* (tulipa-africana), Bignoniaceae.

The number of perianth whorls is used for flower morphology. The term dichlamydeous may be used for flower with calyx and corolla as occur in *Allamanda cathartica* (alamanda-amarela), Apocynaceae (Figure 4A) and *Tabebuia avellanedae* (ipê-roxo), Bignoniaceae. *Monochlamydeous* can be applied for flower with only one whorl, as is seen in *Bougainvillea spectabilis* (primavera or três-marias), Nyctaginaceae (Figure 2A). Flower without perianth is termed achlamydeous one, as verified in Poaceae (Gramineae).

The flowers may be symmetrical or asymmetrical. In the symmetrical flowers can be seen one or more symmetry planes in a floral diagram. Symmetrical flowers can be actinomorphic, bisymmetric and zigomorphic. Actinomorphic or radially symmetric flowers usually exhibit more than two planes of symmetry, with the perianth segments regularly arranged, as may be verified, for example in *Aspidosperma polyneuron*, (peroba-rosa), Apocynaceae and *Solanum paniculatum*, jurubeba, Solanaceae (Figure 4E). Bisymmetric flowers possess only two planes of symmetry. In the zygomorphic flowers there is only one plane of symmetry, with bilabiate flowers or flowers with petals of different size, as occur, for example, in *Eichhornia crassipes* (aguapé), Pontederiaceae (Figure 4D) and in *Spathodea nilotica*, tulipa-africana, Bignoniaceae. Asymmetrical flowers are relatively scarce and they occur in *Canna indica* (biri), Cannaceae (Figure 21E).

Cordia trichotoma (louro or louro-pardo), Boraginaceae is a 20-30 meters tall tree, deciduous pioneer, heliophyte, selective xerophyte, that occurs in more open and secondary semi-deciduous pluvial forest. Its flower (Figure 5A) is dichlamydeous, heterochlamydeous, actinomorphic and hypogynous. The green gamosepalous calyx and white sympetalous corolla persist during the whole development of the fruit until its mature phase, when they acquired the brown color (Figure 5B). The fruit with the perianth constituted the diaspore that presented anemocoric dispersion.



Figure 5 - Flowers(A) and fruits(B) of *Cordia trichotoma*. (ca= calyx; co= corolla)

2.5.1. Calyx

The sepals are usually green, except in *Punica granatum* (romã), Punicaceae in which they are red. The sepal consistence can be fragile or rigid. The format is variable. The sepals have protective function, this applies principally before anthesis, photosynthetic function or they contribute to the fruit dispersion.

The sepals may be united together being the calyx termed gamosepalous. Flowers of *Tabebuia chrysotricha* (ipê-amarelo), *Spathodea nilotica* (tulipa-africana), Bignoniaceae and *Cordia trichotoma* (louro), Boraginaceae (Figure 5A) have gamosepalous calyx. Other flowers present calyx with free sepals in which it is denominated dialysepalous; *Allamanda cathartica* (alamanda-amarela), Apocynaceae has dialysepalous calyx (Figure 4A). The gamosepalous calyx can assume many different forms: bowl-shaped (crateriform), bell-shaped (campanulate), tubular, inflated (ventricose), funnel-shaped (infundibuliform) or urn-shaped (urceolate).

The sepals drop off before anthesis (calyx) or they drop off as soon as the flowers open (deciduos calyx). The calyx may be preserved (persistent calyx) as seen in Asteraceae (Compositae) fruits. In this family the persistent calyx is termed pappus and it contributes to the fruit dispersion.

Sepal anatomy – Sepals are undoubtedly modified leaves and usually present photosynthetic parenchyma. They can present uniseriate epidermis with trichomes and stomata, homogeneous mesophyll and veins with xylem and phloem. A palisade parenchyma in the mesophyll is usually absent.

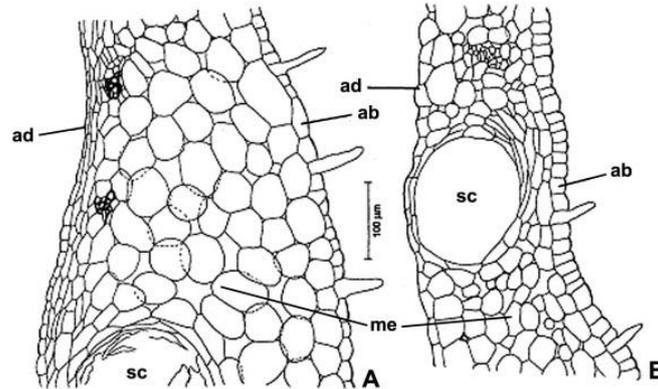


Figure 6 - Flower structure of *Metrodorea nigra* in longitudinal sections. Figs. A, B - Anatomical details of the sepal (A) and petal (B). (ab=abaxial epidermis; ad= adaxial epidermis; me = mesophyll; sc = secretory cavity)

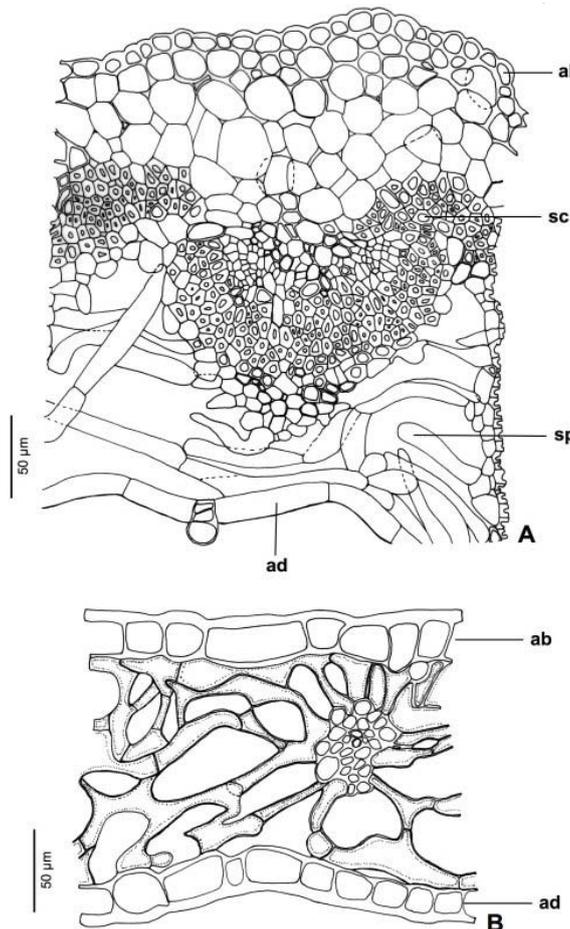


Figure 7 - Flower structure of *Cordia trichotoma* in cross sections. Figs. A, B - Anatomical details of the sepal (A) and petal (B). (ab= abaxial epiderms; ad= adaxial epidermis; sc = sclerenchyma; sp=spongy parenchyma)

Sepals of *Metrodorea nigra* (carrapateira), Rutaceae (Figure 6A) present uniseriate epidermis, which shows stomata and tabular cells only on their adaxial surface. On the

abaxial surface the cells are wider and occur as pointed uni or bicellular non-glandular trichomes, which are accumulated on the margin. The mesophyll is parenchymatic, it presents conspicuous intercellular spaces, and on the adaxial surface, cells vary from more or less spherical to elongated in shape. Cells present chloroplasts, which are more abundant in subepidermal cell layers. Wide secretory cavities are immersed in the parenchymatic mesophyll. Vascularization is made by small collateral vascular strands, situated next to the adaxial surface of the epidermis.

The calyx (Figure 7A) seems to have a double function in the process of *Cordia trichotoma* (louro or louro-pardo), Boraginaceae anemocoric dispersion. The abaxial face epidermis with thick-walled cells and the mesophyll schlerenchyma of the sepals should have a protecting function. On the other hand, mesophyll aerenchyma located under the epidermic adaxial face owes auxiliary in the wind dispersion of the diaspore.

2.5.2. Corolla

The petals are usually colored with variable shape, have delicate texture and great surface area. Also they contain many pigments and fragrance. The life span of petals is variable. They drop off after pollination or may be persistent, as is verified in *Cordia trichotoma* (louro-pardo), Boraginaceae (Figure 5B) which contribute to the fruit dispersion.

Similar to the calyx, the corolla may be gamopetalous or sympetalous (Figure 4A) and dialypetalous or apopetalous (Figures 1B, 2B). In the first case, the petals are united together, as occurs in Bignoniaceae flowers. Dialypetalous corolla has free petals and can be seen in Fabaceae (Leguminosae) flowers.

Petal anatomy (Figure 6B) – Epidermis is uniseriate and may have tector trichomes and papillae. Stomata are not abundant and often are inactive. The mesophyll is usually homogeneous. In the mesophyll may be occur secretory structures. The petal commonly has only one vascular trace what reinforces the theory that in some groups of plants the petal evolved from stamen.

The *Cordia trichotoma* (louro or louro-pardo) corolla (Figure 7B) presents glabrous epidermis, of similar structure in both the faces, with cuticle and cuboid or elongate cells in cross-section. The mesophyll is homogeneous and is constituted of spongy parenchyma. The vascular bundles are collateral and are disposed in the middle area of the mesophyll. The petals with larger superficial area and aerenchymatous mesophyll should only act in the anemocoric dispersion of the diaspore (fruit).

In *Trichilia* species (forest species) the petals have a uniseriate papillose epidermis, with trichomes, stomata and cuticle which can also be ornamented. The papillae occur frequently in the epidermis of the species and show thick cellular walls. The mesophyll is parenchymatic and constituted by cells with thin walls and by secretory cells and cavities. There is a central collateral vascular strand and others of small dimensions immersed in the mesophyll.

2.5.3. Perigone

The perigone is composed of tepals. The tepal form is usually long- or broad-elliptic to ovate or triangular-ovate. The tepals may be petaloid or sepaloid.

In Nyctaginaceae, as *Pisonia aculeata* (espora-de-galo), a forest liana of the south of Brazil, there is perigone (Figure 8A) in the flower which persists in the fruit as anthocarp (Figure 8B). Anthocarp is the lower part of the perigone tube, completely substitutes the real pericarp which is rather obliterated during development.

Tepal anatomy – The tepal has a similar structure to the petal or sepal. The tepal of *Nectandra megapotamica* (canelinha-amarela), Lauraceae has uniseriate epidermis with tector and secretor trichomes and stomata often inactive. The mesophyll is parenchymatous and homogeneous.

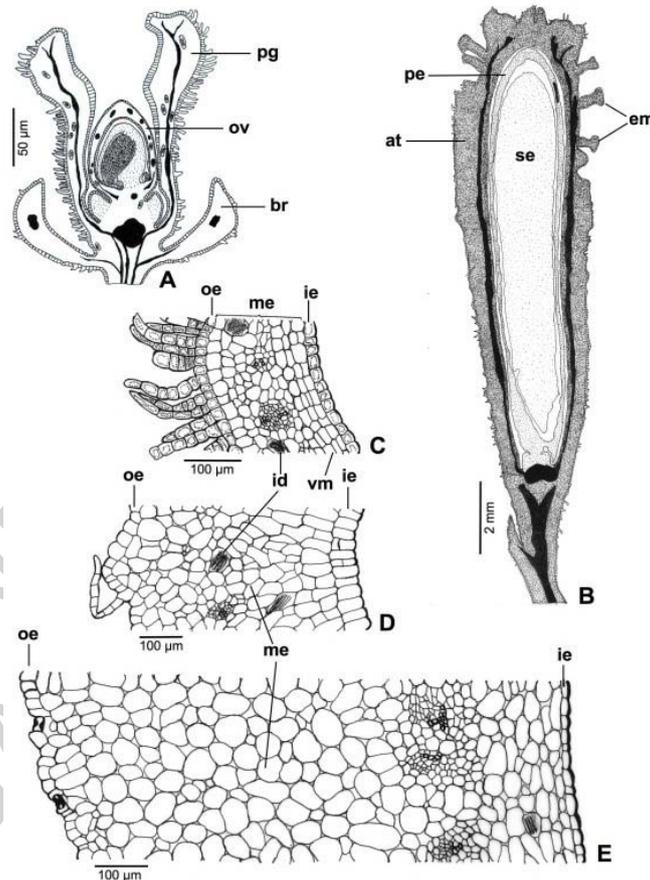


Figure 8 - Perigone and anthocarp structure of *Pisonia aculeata*. Fig. A- Flower diagram in longitudinal section. Fig. B- Anthocarp/fruit diagram in longitudinal section. Fig. C- Perigone detail in cross-section. Figs. D, E- Young and mature anthocarp; br= bract; em= emergencies; id= idioblast with raphides; ie= inner epidermis; me= mesophyll; oe= outer epidermis; ov= ovary; pe = pericarp; pg= perigone; se= seeds; vm= ventral meristem) (Adapted from Souza, 2006)

The perigone of *Sorocea bonplandii* (sorócea), Moraceae (Figure 3B,C) has uniseriate

epidermis with trichomes and stomata, parenchymatic mesophyll with laticifers and crystals.

Pisonia aculeata (espora-de-galo) perigone (Figure 8C) has uniseriate epidermis with tector trichomes. In the surface of the perigone are formed emergences. These emergences persist in the fruit (anthocarp) (Figure 8B), secrete slimy substance and they contribute to the dispersion (zoocory) of fruits in the forest. The mesophyll perigone is homogeneous and parenchymatic (Figure 8C). The perigone becomes the anthocarp (Figure 8D,E) which presents outer epidermis with stomata and emergencies, parenchymatous mesophyll and inner epidermis without trichomes, emergencies and stomata.

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Biographical Sketches

Luiz Antonio de Souza was born in Monte Alto, Brazil, and obtained his undergraduate course in Biology at Universidade Estadual Paulista (Brazil) and postgraduate course in Plant Anatomy at Universidade de São Paulo (Brazil) in 1981. Since 1974 he is professor and researcher of Plant Anatomy at the Universidade Estadual de Maringá (Brazil). Since 2004 he has received research grant from the CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico, Brazil). He has published over 45 papers related to flower, fruit, seed and seedling anatomy.

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