MORPHOLOGICAL NOTES ON THE GENUS CASSIA: I

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In the course of a study of some aspects of the genus *Cassia*, certain features came to light which add to our knowledge of the general morphology of the genus and are of importance in its classification. These are as follows: 1, Comparative morphology of seeds and polyembryony; 2, The vascular pattern in the cotyledons; 3, Types of hairs; 4, Stomatal distribution and morphology; 5, Floral ontogeny and aestivation.

The first three features are discussed in this paper and it is hoped to deal with the other two in subsequent papers.*

For the purpose of reference, the following outline classification of *Cassia* is accepted. For the most part, it agrees with that of Bentham (1871).

1. Subgenus CASSIA.
   Type species: *C. fistula* L.
2. Subgenus SENNA Benth. in Trans. Linn. Soc. Lond. 27: 518 (1871).
   Type species: *C. senna* L.
   - A. Sect. SENNA.
     Type species: *C. senna* L.
   - B. Sect. CHAMAEFISTULA DC. in Colladon, Hist. Cass. 87 (1816).
     Type species: None designated.
   - C. Sect. ONCOLOBIUM (Vogel) Benth. in Trans. Linn. Soc. Lond. 27: 513, 530 (1871).
     Lectotype: *C. occidentalis* L., Sp. Pl. 377 (1753), (cf. Symon, 1966).
   - D. Sect. PROSOSPERMA Vogel, Syn. Cass. 23 (1837).
     Lectotype: *C. tora* L., Sp. Pl. 376 (1753), (cf. Symon, 1966).
   - E. Sect. PSILORHEGMA Vogel, Syn. Cass. 8, 47 (1837).
     Lectotype: *C. glauca* Lam. (*C. surattensis* Burm. f.), (cf. Symon, 1966).
3. Subgenus LASIORHEGMA Benth. in Mart., Fl. Bras. 15, 2: 86, 129 (1870).
   Type species: *C. absus* L.
   - A. Sect. LASIORHEGMA
     Lectotype: *C. absus* L., Sp. Pl. 376 (1753), (cf. De Wit, 1955).
   - B. Sect. APOUCOUITA Benth. in Trans. Linn. Soc. Lond. 27: 513, 557 (1871).
     Type species: *C. apoucouita* Aublet, Pl. Guiana 379, t. 146 (1775), (cf. Symon, 1966).
   - C. Sect. XEROCALYX (Benth.) Irwin in Mem. N.Y. Bot. Gard. 12, 1: 44 (1964).
     Type species: None designated.
   - D. Sect. CHAMAECRISTA (Moench) DC. in Colladon, Hist. Cass. 118 (1816).
     Type species: *C. chamaecrista* L., Sp. Pl. 379 (1753), (*Chamaecrista nictitans* Moench, cf. Symon, 1966).

* This series of papers represents part of the work accepted for the degree of Ph.D. in the University of Edinburgh.

1. Comparative morphology of seeds and polyembryony.

A. Comparative external morphology.

The external morphology of *Cassia* seeds has been fairly well treated in the recently published revisions of De Wit (1955) and Irwin (1964). There are three basic morphological groups as established by Capitaine (1912), and these agree with the three broad subgenera recognised by Bentham (1871).

a) Seeds large, broadly ovate to orbicular with irregular cracks on the seed coats. Apart from these cracks, the surfaces are generally glossy and smooth. Subgenus *Cassia*.

b) Seeds broadly to narrowly ovoid, angled or tapered. All the seeds in this group possess a patch on each face. Subgenus *Senna*.

c) Seeds ovoid to rectangular, trapezoidal and flattened. The surfaces of the seeds are marked with dots which are sometimes arranged in rows. Subgenus *Lasiorhegma*.

In Subgenus *Senna*, the seeds show uniformity in the possession of a patch on each face. This patch was defined by Iseley (1955) as an obovate or enclosed area on each lateral face of the seed. The patch has also been referred to as "face area", "pleurogram" or "areole" by other workers. It is generally lighter-coloured than the rest of the seed surface. These patches have different shapes and can be useful in identification. They are outlined below:—

i. Patch ± circular, e.g. *C. occidentalis*, fig. 1a.
ii. Patch shield shaped, e.g. *C. galeottiana*, *C. obovata*, fig. 1b, c.
iii. Patch broadly ovate, e.g. *C. arnottiana*, fig. 1d.
iv. Patch ovate-lanceolate, e.g. *C. auriculata*, *C. marylandica*, fig. 1e, f.
v. Patch displaced to the edge near the hilum, e.g. *C. alata*, fig. 1g.
vi. Patch elliptic, e.g. *C. pruinosa*, *C. eremophila*, *C. artemisioides*, *C. sturtii*, *C. timorensis*, fig. 1h–l.

B. Comparative internal morphology.

Martin (1946) in his broad survey of the internal seed morphology of different plant families, examined four species of *Cassia*. He observed that in *C. ligustrina*, *C. occidentalis* and *C. fasciculata* the embryo was flat and spatulate. This flat, spatulate embryo is also characteristic of other genera in the Caesalpinioideae and Mimosoideae. In *C. tora*, Martin observed folded cotyledons.

Following this line of investigation, more species of *Cassia* have been examined. The positions of the embryos in transverse and vertical sections have also been ascertained.

The transverse sections were useful in helping to assure correct impressions of shapes and portions of parts. The seeds were also cut vertically to show the embryo to best advantage. In this respect I found that displaying the surface of the embryo was easier and more useful for comparative study than sectioning through the middle of the cotyledons (i.e. exposing only one half of the cotyledons). It was easier to remove the testa and endosperm from one side of the seed leaving the embryo *in situ*, than to cut an accurate half-section through the middle of the seed. Also the pattern of embryo vascularisation was more visible on the outer surface of the

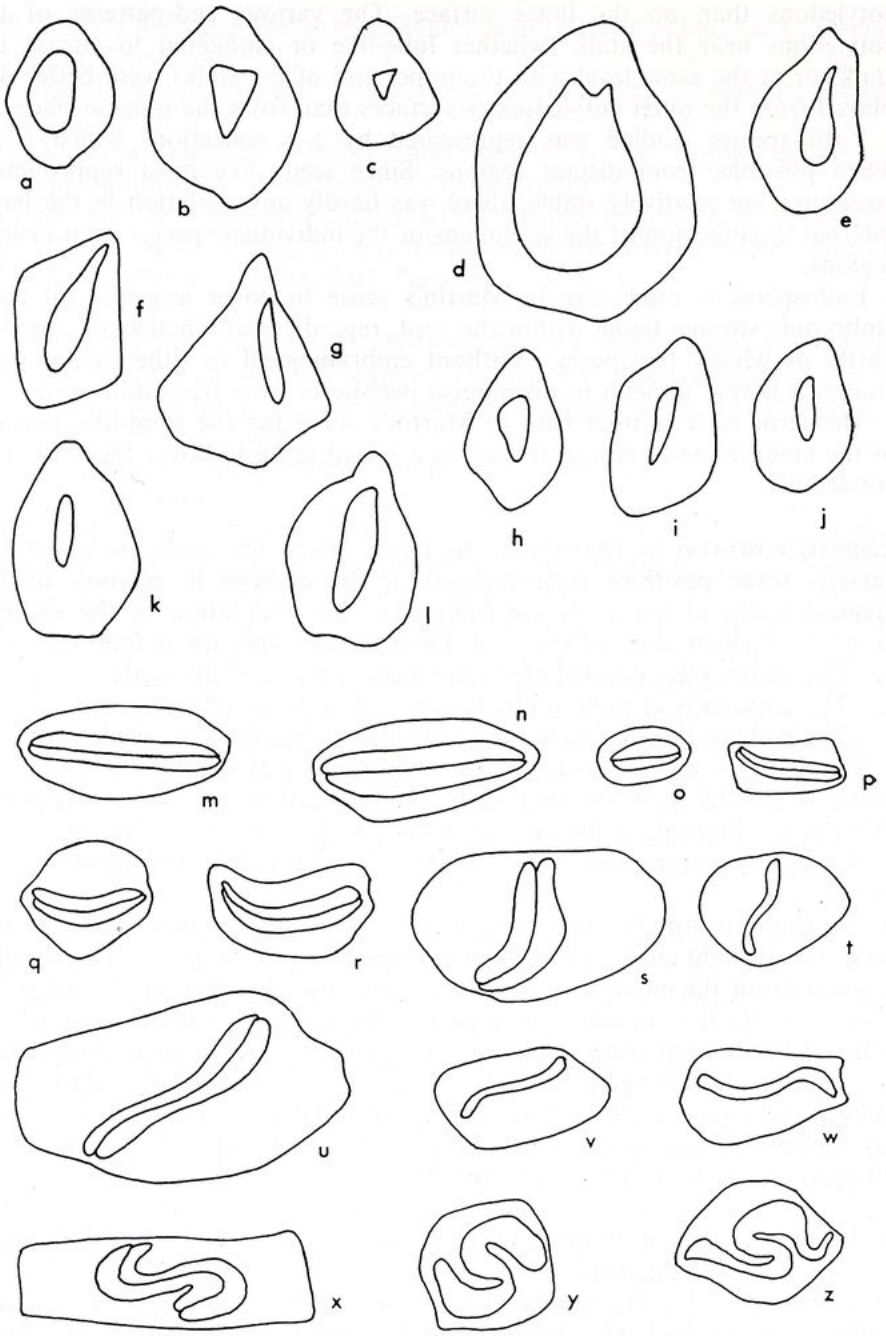

FIG. 1. *Cassia* seeds showing various shapes of patches (a–l) and embryo positions in transverse sections (m–z). a, *C. occidentalis*; b, *C. galeottiana*; c, *C. obovata*; d, *C. arnottiana*; e, *C. auriculata*; f, *C. marylandica*; g, *C. alata*; h, *C. pruinosa*; i, *C. eremophila*; j, *C. artemisioides*; k, *C. sturtii*; l, *C. timorensis*; m, *C. occidentalis*; n, *C. absus*; o, *C. mimosoides*; p, *C. bahamensis*; q, *C. sulcata*; r, *C. corymbosa*; s, *C. fistula*; t, *C. javanica*; u, *C. grandis*; v, *C. nodosa*; w, *C. sophera*; x, *C. alata*; y, *C. tora*; z, *C. uniflora*. m, n, o, p, q, r, x, y, z × 15, the rest × 7·5.

cotyledons than on the inner surface. The various end-patterns of the cotyledons near the stalk (whether lobe-like or elongated to encase the stalk, or at the same level with the upper end of the stalk) were better displayed from the outer cotyledonary surfaces than from the inner surfaces.

Each species studied was represented by 2–3 collections which were, when possible, from distant regions. Since seeds like most reproductive structures are relatively stable, there was hardly any variation in the basic internal organisation of the specimens of the individual species from distant regions.

Endosperm is used here in Martin's sense to cover any and all non-embryonic storage tissue within the seed, regardless of whether or not it is partly or wholly perisperm. Without embryological or other histological studies it is very difficult to distinguish perisperm from true endosperm.

The term stalk is used here in Martin's sense for the stem-like portion of the embryo, and embryo is used in a broad sense to cover the stalk and cotyledons.

EMBRYO POSITIONS IN TRANSVERSE SECTIONS. When the seeds are cut transversely, three positions (orientations) of the embryo in relation to the greatest width of the seeds are found, i.e. the orientation of the embryo along the median plane of the seed. These orientations are as follows:

1, The embryo lies parallel along the median plane of the seed;
2, The embryo is at right angles to the median plane of the seed;
3, The embryo lies obliquely along the median plane of the seed.

The embryos are variously shaped in relation to the above three orientations. It should be noted that in transverse sections, it is the cotyledons that are cut through at the greatest width of the seed. The different shapes of the embryo found among the seeds are given below and illustrated in fig. 1.

A. (i) Embryo straight and lying parallel along the median plane of the seed. The straight embryo is by far the commonest in the genus. The parallel orientation of the embryo is also the commonest. Apart from the subgenus *Cassia*, where it is absent, this type of embryo and its orientation is distributed throughout other subgenera, e.g. Subgen. *Senna*, Sect. *Oncolobium* (*C. occidentalis*), Subgen. *Lasiorhegma*, Sect. *Lasiorhegma* (*C. absus*) and Subgen. *Lasiorhegma*, Sect. *Chamaecrista* (*C. mimosoides*), fig. 1m–o.

(ii) Embryo straight and oblique along the median plane, e.g. *C. bahamensis* (Subgen. *Senna* Sect. *Senna*), fig. 1p.

B. Embryo C-shaped. In this group there are various degrees of C-formation but it is generally distinct.

(i) C-shaped and lying parallel along the median plane, e.g. *C. sulcata* (Subgen. *Senna*, Sect. *Oncolobium*) and *C. corymbosa* (Subgen. *Senna*, Sect. *Chamaefistula*), fig. 1q, r.

(ii) C-shaped and lying at right angles to the median plane, e.g. *C. fistula* (Subgen. *Cassia*), fig. 1s.

C. Embryo S-shaped (sigmoid). In this group also are to be found various degrees of S-formation, but they are distinct from the two types above.

(i) Weakly S-shaped and oblique to the median plane, e.g. *C. grandis* (Subgen. *Cassia*), fig. 1u.

(ii) Weakly S-shaped and at right angles to the median plane, e.g. *C. javanica* (Subgen. *Cassia*), fig. 1t.
(iii) Sigmoid and oblique to the median plane, e.g. *C. nodosa* (Subgen. *Cassia*), fig. 1v.
(iv) Sigmoid (median S-shaped) and parallel to the median plane, e.g. *C. sophera* (Subgen. *Senna*, Sect. *Oncolobium*), fig. 1w.
(v) Strongly S-shaped and parallel to the median plane, e.g. *C. alata* (Subgen. *Senna*, Sect. *Senna*), *C. tora* (Subgen. *Senna*, Sect. *Prososperma*) and *C. uniflora* (Subgen. *Senna*, Sect. *Prososperma*). fig. 1x–z.

EMBRYO POSITIONS IN VERTICAL SECTIONS. Martin (1946) recognised different types of embryo in vertical sections. The types of embryo given below are selected from Martin's key to the embryo types in so far as they apply to the types found in *Cassia*.

Key to types of *Cassia* embryo (adopted from Martin).

1.	Embryo erect	2
+	Embryo with folded cotyledons	Folded
2.	Stalk not invested with cotyledons or only slightly so .	Spatulate
+	Stalk invested with cotyledons half of length or more .	Investing

The spatulate embryo is the commonest of the three types. In Subgenus *Cassia* as illustrated in fig. 2a–d, the embryos are more or less centrally placed in the seeds and the proportions of the endosperm on either side of the embryos are more or less equal. Many species in Subgenus *Senna* possess the spatulate type of embryo, e.g. *C. atomaria* (Sect. *Senna*), *C. occidentalis* (Sect. *Oncolobium*), *C. alata* (Sect. *Senna*), *C. obovata* (Sect. *Senna*). In these species, as is evident in fig. 2e–l, the cotyledons have become expanded and occupy more space inside the seeds and the proportions of endosperm are correspondingly reduced. This contrasts with the species in Subgenus *Cassia*.

The investing type of embryo where the cotyledons encase the somewhat dwarf stalk for at least half its length is found in *C. bicapsularis* (Subgen. *Senna*, Sect. *Chamaefistula*) and *C. absus* (Subgen. *Lasiorhegma*, Sect. *Lasiorhegma*)—fig. 2i, j.

The occurrence of two or three embryos in the seed (polyembryony) sometimes gives a false appearance of different lengths of the stalks.

The folded type of embryo (S-shaped or sigmoid) is found in *C. tora* and *C. uniflora*, both in Subgen. *Senna*, Sect. *Prososperma*.

C. THE PHENOMENON OF POLYEMBRYONY.

During the investigation of the internal morphology of *Cassia* seeds involving the cutting of transverse and vertical sections, seeds with more than one embryo were found. This led to the examination of many seeds of *Cassia* in order to determine how widespread the phenomenon is in the genus.

Symon (1956) recorded polyembryony in six Australian species of *Cassia*, all belonging to Sect. *Psilorhegma* in Subgen. *Senna*.

Seeds were obtained from the fruits of herbarium specimens at Edinburgh and these were carefully dissected to expose the embryos to best advantage. In some cases seeds with one, two or three embryos were found in the same fruit. As illustrated in fig. 2, the embryos of the seeds are unequal in size. In *C. eremophila*, (fig. 2m), one of the twin embryos was larger

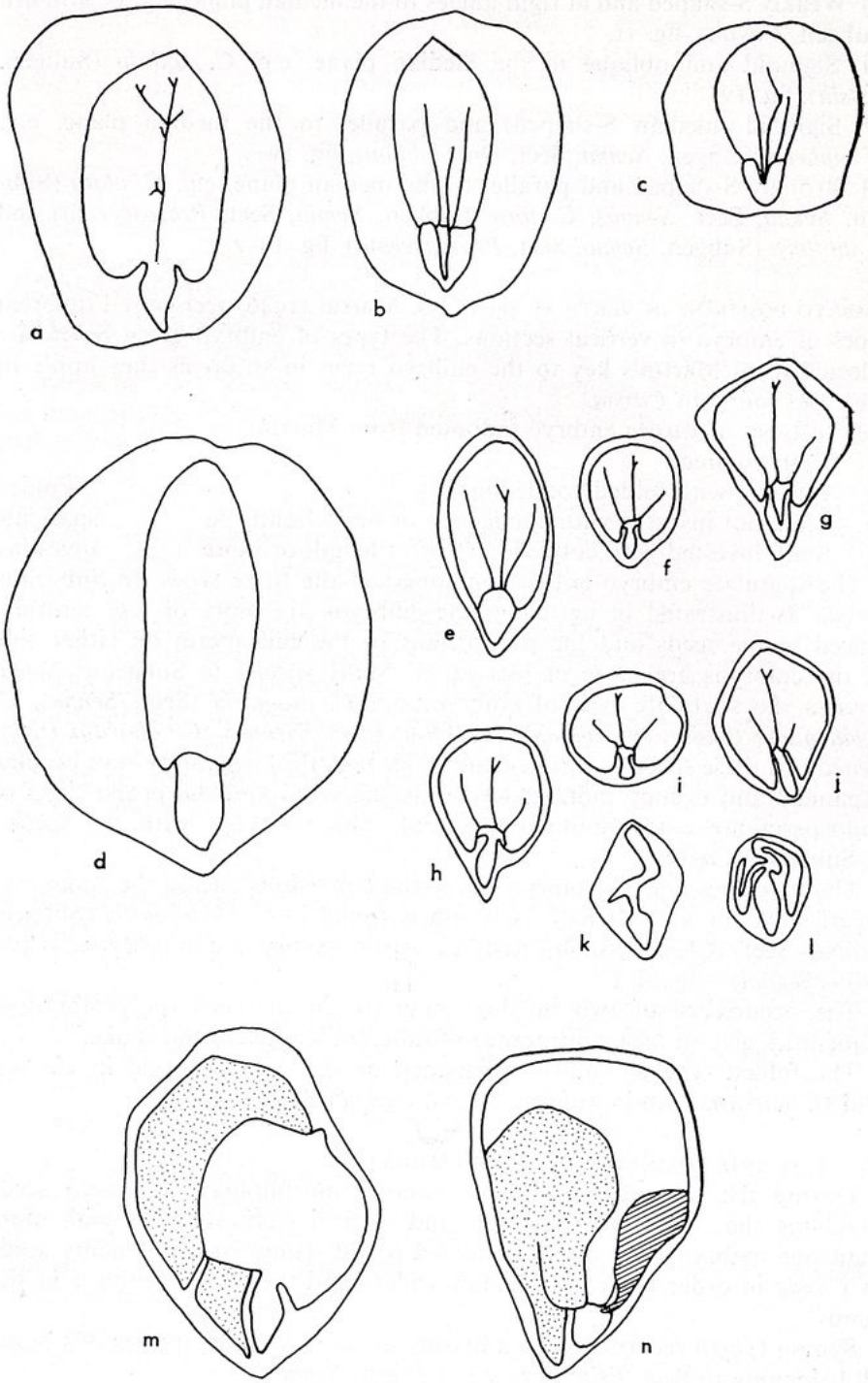

FIG. 2. *Cassia* seeds showing embryo positions in vertical sections (a–l) and polyembryony (m, n). a, *C. fistula*; b, *C. nodosa*; c, *C. javanica*; d, *C. grandis*; e, *C. atomaria*; f, *C. occidentalis*; g, *C. alata*; h, *C. obovata*; i, *C. bicapsularis*; j, *C. absus*; k, *C. tora*; l, *C. uniflora*; m, *C. eremophila*; n, *C. pruinosa*. a–l × 7·5, m–n × 15.

than the other. In *C. pruinosa*, (fig. 2n), the triplet embryos are unequal in size. In the small embryos the cotyledons are correspondingly reduced.

In table I, the distribution of the embryos in seeds of those species where polyembryony has been observed is given. All belong to Sect. *Psilorhegma*. Two of these species (*C. oligophylla* and *C. pruinosa*) were not recorded by Symon (1956).

Table I

Species	Collector	Locality	No. of embryos
C. oligophylla F. Muell.	Alex. Morrison	W. Australia, Ashburton.	1, 2.
C. sturtii R. Br.	T.R.N. Lothian 2796, 9 iv 1964	S. Australia, N.W. Plains.	1, 2.
C. pruinosa F. Muell.	Alex. Morrison, 1 x 1905	W. Australia, Ashburton River.	1, 2, 3.
C. artemisioides Gaud.	Max Koch 176	S. Australia, Mt. Lyndhurst.	1, 2.
C. eremophila A. Cunn.	F. E. Victor, 8 ii 1911	W. Australia, Kununoppin.	1, 2, 3.

I have not found polyembryos from seeds in other sections of the genus, but the extent of the distribution of the phenomenon in the genus must await a more detailed investigation.

From the two embryos in the seed of *C. sturtii*, I was able to raise two seedlings. The seedlings were unequal in size, which tends to correspond to the initial sizes of the embryos and probably also to the unequal distribution of food substances in them. The fact that both seedlings were able to germinate and grow demonstrates the viability of both embryos.

In the absence of embryological and developmental studies, it is not possible to explain the origin of these embryos; one can only speculate that they might have arisen from one or several sources such as cleavage polyembryony or apomictic embryos.

2. The vascular pattern in the cotyledons.

The vascular pattern in the cotyledons of many plant families has always been an interesting aspect of study. The patterns obtained in the past were used as one of the lines of evidence to illustrate the evolutionary trend of certain characters in the angiosperms.

The cotyledons used in the study of the vascular pattern were obtained from germinated seedlings grown at the Royal Botanic Garden, Edinburgh. Since at maturity the cotyledons are sessile, they were carefully removed from the seedlings so that part of the stem portion enclosing the vascular system continuous with that of the cotyledons was attached. To facilitate clearing, the cotyledons were dried between filter papers for a period varying from one to three or four days. The dried cotyledons were then cleared by the technique of Arnott (1959).

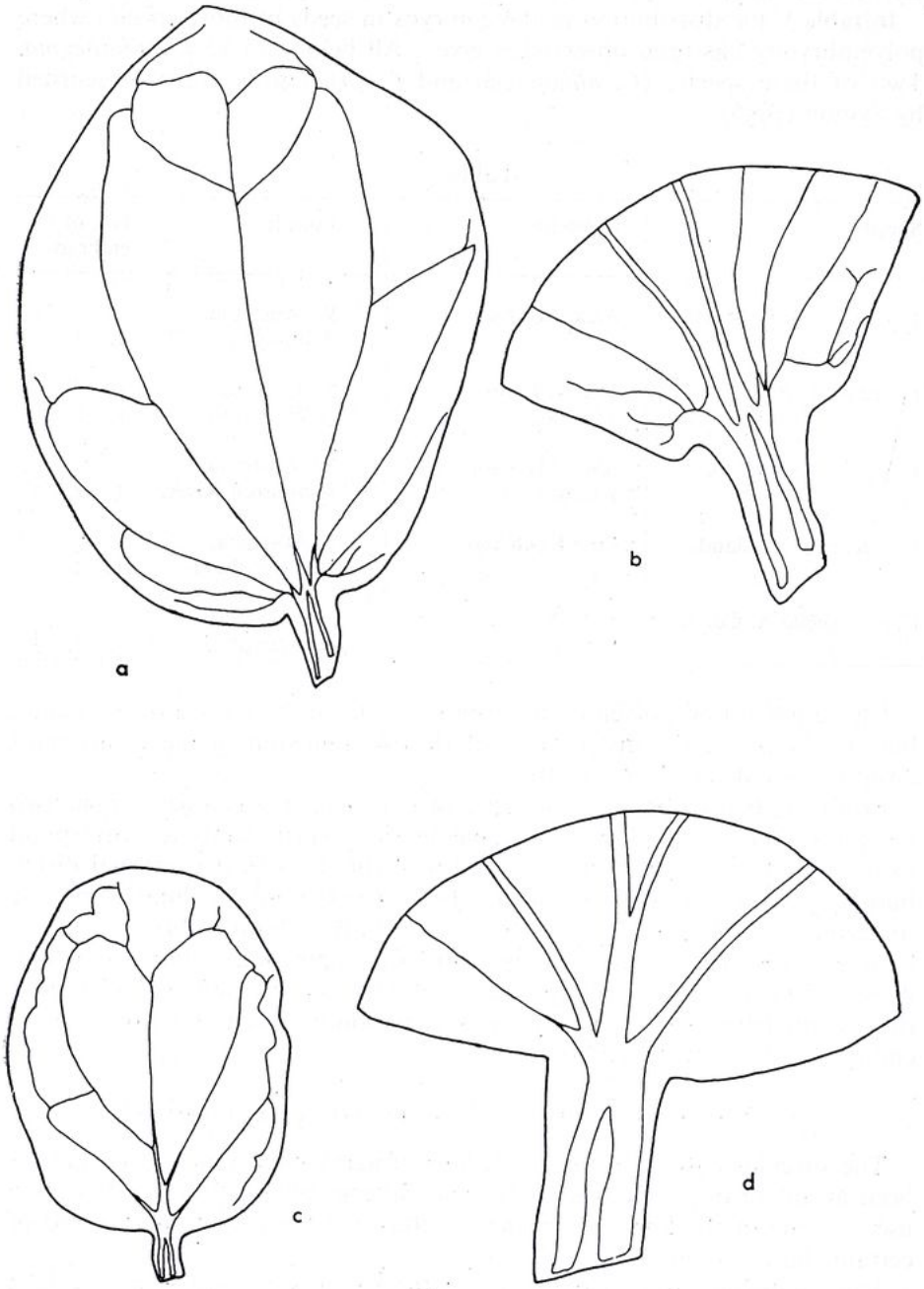

FIG. 3. Vascular pattern in the cotyledons of *Cassia*. a, *C. aeschynomene*; b, details of venation at base of a; c, *C. laevigata*; d, details of venation at base of c. a & c × 15, b & d × 31·25.

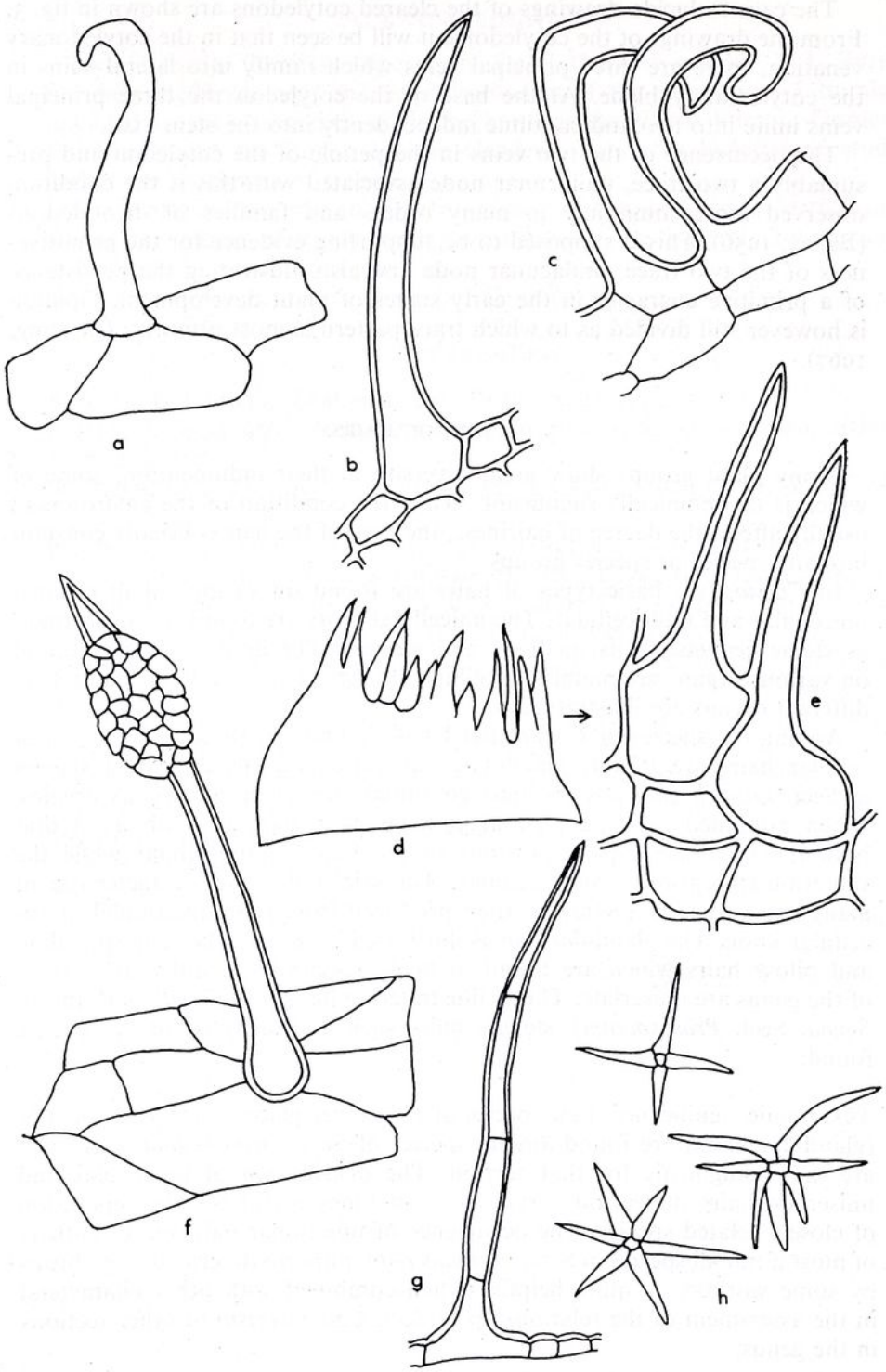

FIG. 4. Types of hairs in *Cassia*. Unicellular hairs from a, *C. fistula* leaflet; b, *C. mimosoides* fruit; c, *C. mimosoides* anther; d, *C. mimosoides* stigma; e, detail of d; f, glandular hair from *C. barbata* leaflet; g, uniseriate hair from *C. rotundifolia* stem; h, stellate hairs from *C. villosa* leaflet. b, c, g, h × 100, the rest × 400.

The camera lucida drawings of the cleared cotyledons are shown in fig. 3. From the drawings of the cotyledons, it will be seen that in the cotyledonary venation, there are three principal veins which ramify into lateral veins in the cotyledonary blade. At the base of the cotyledon the three principal veins unite into two and continue independently into the stem axis.

The occurrence of the two veins in the petiole of the cotyledon and presumably a two trace, unilacunar node associated with this is the condition observed most commonly in many orders and families of dicotyledons (Bailey, 1956). This is supposed to be supporting evidence for the primitiveness of the two trace, unilacunar node and also illustrating the persistence of a primitive character in the early stages of plant development. Opinion is however still divided as to which trace pattern is most primitive (Benzing, 1967).

3. Types of hairs.

Many plant groups show great diversity in their indumentum, some of which is taxonomically significant. While the condition of the environment usually affects the degree of hairiness, the type of the hair is usually constant in many species or species groups.

In *Cassia*, two basic types of hairs are found on various plant organs: unicellular and multicellular. The unicellular hairs are found on such organs as stems, leaflets, fruits, pedicels and anthers. The appressed hairs found on various organs are mainly unicellular. In fig. 4a–e, unicellular hairs from different organs are illustrated.

Among the species of *Cassia* that I have examined, three types of multicellular hairs are found: glandular, uniseriate and stellate. Most species in Sect. *Lasiorhegma* possess hairs commonly described as viscous bristles. When examined under a high magnification (x 400), it is observed that both the basal and apical portions of the hair are unicellular while the subterminal portion is multicellular. The sticky fluid so characteristic of many species in this section is often produced from this subterminal multicellular knob. The glandular hair is illustrated in fig. 4f. The long spreading and pilose hairs which are found in many species from different sections of the genus are uniseriate. This is illustrated in fig. 4g. In *C. villosa* (Subgen. *Senna*, Sect. *Prososperma*), stellate hairs such as illustrated in fig. 4h are found.

Taxonomic significance. Few species of *Cassia* are glabrous. Viscous bristles (glandular hairs) are found among species of Sect. *Lasiorhegma*, and these are quite diagnostic for that section. The distribution of unicellular and uniseriate hairs on various organs is sometimes useful for the separation of closely related species. The occurrence of unicellular hairs on the anthers of most if not all species in Sect. *Chamaecrista*, hitherto described as glabrous by some workers, is quite helpful (when combined with other characters) in the assessment of the relationship of Sect. *Chamaecrista* to other sections in the genus.

Acknowledgments

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