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Ontogeny of the tricytic stoma—Variations and modifications

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Abstract. The tricytic stoma is studied on the basis of published literature and illustrations. It is found that it may be formed in a variety of ways. These are classified and reviewed.

Keywords. Anisocytic ; tricytic ; stoma ; ontogeny ; variations.

1. Introduction

Metcalfe and Chalk (1950) defined the anisocytic stoma as a " stoma surrounded by three cells of which one is distinctly smaller than the other two ". Earlier Vesque (1889) named such stomata as ' Cruciferous " and cited the family Cruciferae as a typical example. Pant and Kidwai (1966) and Kidwai (1974) designated all stomata surrounded by three cells as tricytic. It is suggested that the term tricytic be used generally for all types of stomata surrounded by three cells irrespective of their size or ontogeny whereas anisocytic be restricted to those where one of the subsidiaries is distinctly smaller than the others. Development of this type of stoma has been described in a number of plants. Typically it is formed mesogenously from a trilabrate initial which forms walls in a spiral manner so that the first formed cell is largest and the last formed one the smallest.

It was generally believed that the development of this type of stoma is fairly constant (Farooqui 1979), but a survey of recent literature has revealed that it may be formed by varied ontogenetic pathways (figure 1).

2. Ontogenetic pathways

2.1. *Perigenous*

The stomatal meristemoid divides directly to give rise to the two guard cells and the stoma thus formed is surrounded by three normal epidermal cells which

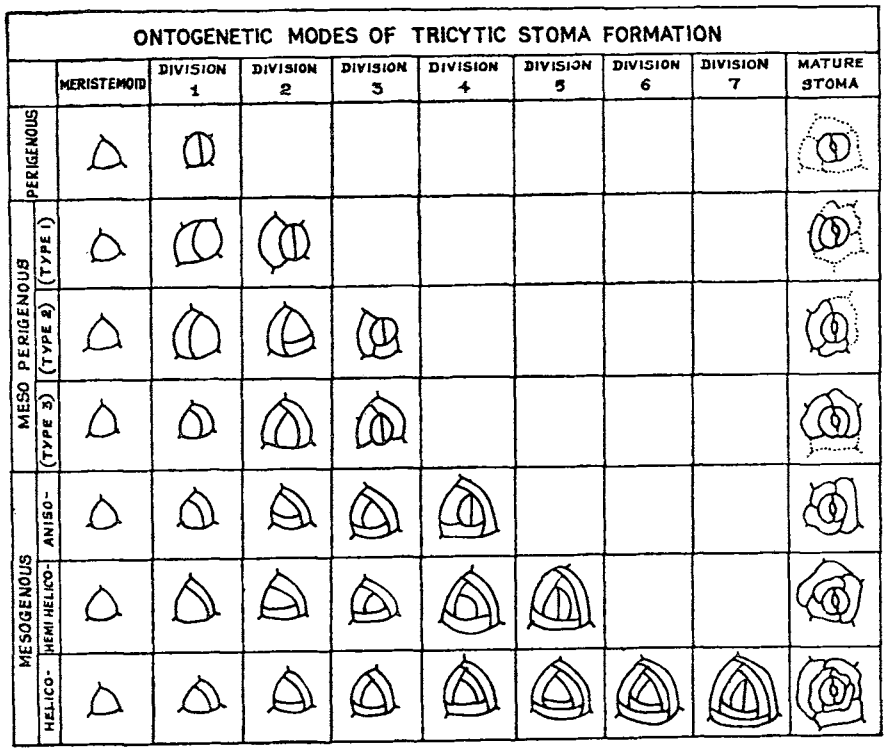

Figure 1. Diagrammatic representation of the different ontogenetic modes of tricytic stoma formation. 1.1. Perigenous. 1.2 (a). Mesoperigenous type 1. 1.2 (b). Mesoperigenous type 2. 1.2 (c). Mesoperigenous type 3. 1.3 (a). Aniso-mesogenous. 1.3 (b). Hemi-helico-mesogenous. 1.3 (c). Helico mesogenous.

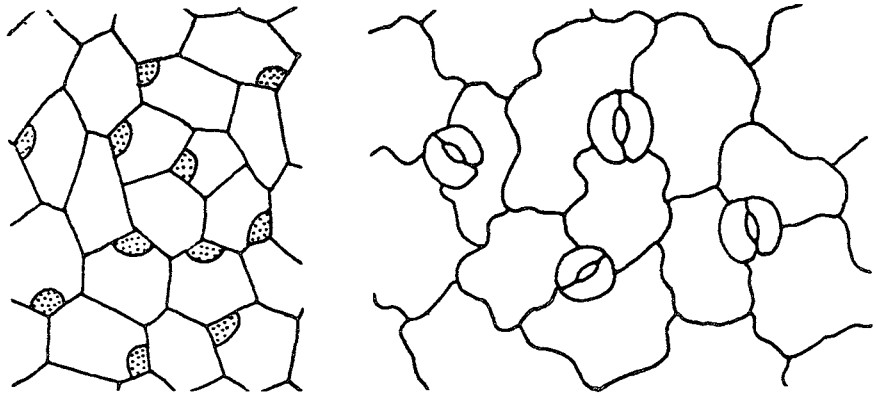

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Figure 2. Diagrammatic representation of cell arrangement in the protoderm showing triangular meristemoids (dotted) surrounded by three cells each.

Figure 3. Tricytic stomata formed directly from meristemoids as in figure 2 without divisions in the surrounding cells.

happen to lie around the guard cells (figure 1.1) or by cells formed from divisions of perigene cells. When a meristemoid is formed in the corner of a cell, it is usually surrounded by three cells (figure 2). If such a meristemoid directly behaves as the guard cell mother cell and there are no divisions in the surrounding cells the guard cells become surrounded by three perigene cells only (figure 3). This is designated here as the "triperigenous" type in accordance with the general terminology of Fryns-Claessens and Van Cotthem (1973), *e.g.* some stomata of *Zamioculous* (Pant and Kidwai 1966a); *Elaeodendron* (Pant and Kidwai 1966b), *Bougainvillaea spectabilis* (Inamdar 1968), *Carica papaya* (Pant and Banerjee 1965a).

2.2. *Mesoperigenous*

The subsidiary cells in this type are of dual origin, one or two being formed from the stomatal mother cell, the rest being perigenes (figure 1.2).

2.2a *Aniso- or tri-mesoperigenous type I* : Here only one cell is formed from the stomatal meristemoid before it divides into the two guard cells (figure 1.2a). The other two subsidiaries are of perigene origin *e.g.* some stomata of *Anagallis* (Verma 1972), *Carica papaya* (Pant and Banerjee 1965a), *Fumaria* (Kidwai 1972) and *Leea* (my unpublished observations).

2.2b. *Aniso- or tri-mesoperigenous type* 2 : The stomatal meristemoid divides by two intersecting walls at right angle to each other to form two subsidiary cells which are arranged in a "L" shaped manner. The guard cells are then formed by an equatorial division in the meristemoid. The third subsidiary cell represents a perigene cell (figure 1.2b), e.g. some stomata in Piperaoeae (Pant and Banerjee 1965b), *Cucumis* and *Tagetes* (Ramayya and Rao 1968) and *Lactuca* (Pant and Kidwai 1972).

2.2c. *Aniso- or tri-mesoperigenous type* 3 : Here two lateral subsidiary cells are formed mesogenously as in a paracytic stoma but due to the non-intersection of their walls at one of the poles, the guard cells come to be surrounded by an additional perigene cell (figure 1.2c) e.g. some stomata in Papilionaceae (Shah and Gopal 1969a, b), *Polygonum glabrum* (Kapoor *et al* 1971) and *Dipteris* (Khare 1978).

2.3. *Mesogenous*

This is the typical type where the stomatal meristemoid cuts off 3 unequal cells in a spiral sequence before becoming the guard cell mother cell (figure 1.3).

2.3a. *Aniso-mesogenous* : There are only three mesogenous subsidiary cells around the guard cells (figure 1.3a), e.g. *Nicotiana* (Esau 1953), *Begonia* (Dehnel 1961) *Notonia* (Pant and Verma 1963), Convolvulaceae (Pant and Banerjee 1965c), Cruciferae (Pant and Kidwai 1967; Landré 1972) Araliaceae (Inamdar *et al* 1969), Malvaceae and Bombacaceae (Inamdar and Chohan 1969; Kidwai 1974), *Kalanchoe* (Inamdar and Patel 1970), *Barringtonia* (Farooqui 1979) and some stomata in Polygonales and Centrospermae (Inamdar 1969), *Phyla* (Pant and Kidwai 1964), *Crotalaria* (Shah and Gopal 1969) and *Dipteris* (Khare 1978).

2.3b. *Helico-mesogenous* : A more specialised form of the anisomesogenous type, where the meristemoid continues to divide in the same spiral sequence even after the formation of three subsidiary cells to form a total of 4–6 or more subsidiaries and encircling cells (figure 1.3c), e.g. Bigoniaceae, Crassulaceae, Cruciferae, Gesneriaceae, Malvaceae, Polygonaceae, Utricaceae, Violaceae (Payne 1970), Myrsinaceae (Metcalfe and Chalk 1950), Compositae (Pant and Verma 1963) and *Kalanchoe* (Inamdar and Patel 1970). Where only one additional cell is formed, the stoma may be designated Hemi-helico-mesogenous (figure 1.3b).

3. Discussion

The anisocytic stoma is a very interesting type being formed by at least six or seven different pathways. Even after its formation, this type of stoma is not without its variations, e.g. an additional mesogene segment may be formed as in a helico-mesogenous type of stoma and if the first three walls do not intersect, a tetracytic stoma results as in *Bombax* (Kidwai 1974).

Tetracytic and anomocytic stomata may also be formed from anisocytic ones by divisions in their subsidiaries and the guard cells becoming surrounded by 4–5 or more cells, e.g., some stomata of *Notonia* (Pant and Verma 1963), *Crotalaria* (Shah and Gopal 1969) and *Bombax* (Kidwai 1974).

In *Begonia* (Dehnel 1961) and the Cruciferae (Pant and Kidwai 1967; Landre 1972), the mesogene segments behave as meristemoids and give rise to additional stomata resulting in their aggregation into small groups.

Sometimes a meristemoid which is trilabrate at first becomes dolabrate and the guard cells are enclosed by two parallel subsidiaries which in turn are surrounded by three mesogene cells, e.g., some stomata of *Malpighia glabra* (Verma 1979).

With so many developmental types leading to the formation of a single type of stoma, clearly, there is an urgent need to study the development of this type of stoma on a wider scale.

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References

Dehnel G S 1961 Abnormal stomatal development in foliage leaves of *Begonia aridicaulis* ; *Am. J. Bot.* **48** 129–133

Esau K 1953 *Plant Anatomy* (New York and London : John Wiley and Sons)

Farooqui P 1979 Development of stomata in *Barringtonia racemosa* Roxb. ; *Curr. Sci.* **48** 601–603

Fryns-Claessens E and Van Cotthem W 1973 A new classification of the ontogenetic types of stomata ; *Bot. Rev.* **39** 71–138

Inamdar J A 1968 Epidermal structure and ontogeny of stomata in some Nyctaginaceae ; *Flora* **158** 159–166

Inamdar J A 1969 Epidermal structure and stomatal ontogeny in some Polygonales and Centrospermae ; *Ann. Bot.* **33** 341–352

Inamdar J A and Chohan A J 1969 Epidermal structure and stomatal development in some Malvaceae and Bombacaceae ; *Ann. Bot.* **33** 865–878

Inamdar J A, Gopal B Y and Chohan A J 1969 Development of normal and abnormal stomata in some Araliaceae ; *Ann. Bot.* **33** 67–73

Inamdar J A and Patel R C 1970 Structure and development of stomata in vegetative and floral organs of three species of *Kalanchoe* ; *Ann. Bot.* **34** 965–974

Kannabiran B 1975 Epidermal structure and stomatal ontogeny in *Zornia* Gmel.; *Aust. J. Bot.* **23** 327–333

Kapoor S L, Sharma P C and Kapoor L D 1971 Epidermal and venation studies in the Indian species of *Polygonum* Linn. (Polygonaceae)—I ; *Bull. Bot. Surv. India* **13** 244–259

Khare P K 1978 Epidermal structure and ontogeny of stomata in *Dipteris wallichii* ; *Phytomorphology* **28** 400–405

Kidwai P 1972 Development of stomata in some Papaveraceae and *Fumaria* ; *Ann. Bot.* **36** 1011–1016

Kidwai P 1974 Epidermal structure and stomatal development in *Bombax ceiba* L. ; *Bot. J. Linn. Soc.* **68** 227–234

Landré P P 1972 Origine et développement des épidermes cotylédonaries et foliaires de la Moutarde (*Sinapis alba* L.) Différenciation ultrastructurale des stomates ; *Ann. Sci. Nat.* **13** 247–322

Metcalfe C R and Chalk L 1950 *Anatomy of the dicotyledons* (Oxford : Clarendon Press)

Pant D D and Banerjee R 1965a Ontogeny of stomata and hairs in some cucurbits and allied plants ; *J. Indian Bot. Soc.* **44** 191–197

Pant D D and Banerjee R 1965b Structure and ontogeny of stomata in some Piperaceae ; *J. Linn. Soc. (Bot.)* **59** 223–228

Pant D D and Banerjee R 1965c Epidermal structure and development of stomata in some Convolvulaceae ; *Senck. Biol.* **46** 155–173

Pant D D and Kidwai P 1964 On the diversity in the development and organization of stomata in *Phyla nodiflora* Michx. ; *Curr. Sci.* **33** 653–654

Pant D D and Kidwai P 1966a Structure of leaves and stomatal ontogeny in some Pandanales and Spathiflorae ; *Senck. Biol.* **47** 309–333

Pant D D and Kidwai P 1966b Epidermal structure and stomatal ontogeny in some Celastraceae ; *New Phytol.* **65** 288–295

Pant D D and Kidwai P 1967 Development of stomata in some Cruciferae ; *Ann. Bot.* **31** 513–521

Pant D D and Kidwai P 1972 Development of stomata in *Lactuca sativa* L. ; *Ann. Bot.* **36** 123–145

Pant D D and Verma B K 1963 Development of stomata in leaves of *Notonia grandiflora* DC ; *J. Indian Bot. Soc.* **42** 384–391

Payne W W 1970 Helicocytic and Allelocytic stomata, unrecognized patterns in the Dicotyledonae ; *Am. J. Bot.* **57** 140–147

Ramayya N and Rao B R 1968 On the classification of certain Angiospermous stomata ; *Curr. Sci.* **37** 662–664

Shah G L and Gopal B V 1969a Stomatal ontogeny of the vegetative and floral organs of some Papilionaceae ; *Aust. J. Bot.* **17** 81–87

Shah G L and Gopal B V 1969b Development of stomata in some Papilionaceae ; *Can. J. Bot.* **47** 387–393

Shah G L and Gopal B V 1969c Ontogeny of stomata on the foliar and floral organs of some species of *Crotalaria* L. ; *Ann. Bot.* **33** 553–560

Trivedi B S and Upadhyay N 1976 Ontogeny of stomata in some members of Apocynaceae ; *Geophytol.* **6** 92–97

Trivedi B S and Upadhyay N 1977 Morphological studies in Apocynaceae—Epidermal structures ; *Geophytol.* **7** 29–37

Verma B K 1972 Epidermal structure and ontogeny of stomata in leaves of *Anagalis arvensis* L. ; *Ann. Bot.* **36** 857–860

Verma B K 1979 Development of stomata in leaves of *Malpighia glabra* Linn. ; *Geophytol.* **8** 205–208

Vesque J 1889 De l'emploi des caracteres anatomiques dans la classification des végétaux ; *Bull. Soc. Bot. Fr.* **36** 41–77