STRUCTURE AND DISTRIBUTION OF THE EPIDERMAL ELEMENTS IN THE ANGIOSPERMS I. EPIDERMAL CELL COMPLEX

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ABSTRACT

The study deals with structure and distribution of the elements of epidermal cell complex in angiosperms. Variation in epidermal cell characters, viz., shape, anticlinal and periclinal walls, cytoplasmic contents, sculpturing of outer walls, arrangement and orientation have been presented. The epidermal cell distribution patterns have been found to be related to whether the cells are predominantly anisodiametric or isodiametric. With reference to anisodiametric cells 20, and to isodiametric cells six, distribution patterns including some hypothetical ones, are recognisable. The characters of the epidermal cells as well as their distribution patterns, when taxonomically consistent, are of value in identifying a whole plant or its parts.

INTRODUCTION

Importance of studies in angiosperm epidermis is currently well recognised as evidenced by the numerous recent publications and reviews on the subjects (COWAN, 1950; METCALFE, 1960; TOMLINSON, 1961; 1969; UPHOF, 1962; DUNN *et al.*, 1965; ESAU, 1965; STACE, 1965; MEIDNER & MANSFIELD, 1968; CUTLER, 1969; MARTIN & JUNIPER, 1970; LUTTAGE, 1971; AYENSU, 1972; RAMAYYA, 1972; FRYNS-CLAESSENS & VAN COTTHEM, 1973; LEVIN, 1973; RAJAGOPAL, 1973; DILCHER, 1974; HESLOP-HARRISON & HESLOP-HARRISON, 1975; JOHNSON, 1975; LEELAVATHI, 1976; WILKINSON, 1979). But of the different components of the epidermis, the epidermal cell complex, however, seems to have received lesser attention than others. Earlier publications on this subject include those of SOLEREDER (1908), MECALFE AND CHALK (1950), MATCALEE (1960, 1971), TOMLINSON (1961, 1969), CUTLER (1969) AND AYENSU (1972. In retrospect, the available information in this area seems to be comparatively scanty and especially there is little that is known about the general characters of structure and distribution of the epidermal cell complex. This work has been taken up to fill in this gap. The paper also analyses the data available on the structure and distribution of the elements the epidermal cell complex in the angiosperms from the past literature (METCALEE, 1960; TOMLINSON, 1961; 1966; GUPTA *et al.*, 1965; SHAH & GOPAL, 1970; GHOSE & DAVIS, 1973; RAJAGOPAL, 1973; STANT, 1973; CLARK & GOULD, 1975; DAYANANDAN & KAUFMAN, 1976; CUTLER & BRANDHAM, 1977; RAJU & RAO, 1977; TRIVEDI *et al.*, 1978; RUDALL, 1980; BRANDHAM & CUTLER, 1981).

MATERIAL AND METHOD

The authors have studied the epidermis of 209 species of divergent angiospermous taxa (Table 1). Mature leaves were fixed in acetic-alcohol (1 : 3). Epidermal peels were taken from leaves by scraping with a scalpel. For difficult materials, the "Double-treatment method of LEELAVATHI AND RAMAYYA (1975) was employed. In most of the species, the peels of at least five specimens were studied from base, middle and apex regions, covering from midvein to the margin. Where leaves are

Table 1—List of species investigated

ASCLEPIADACEAE

1. *Calotropis gigantea* (Willd.) Dry & Ex Ait. F.
2. *Cryptostegia grandiflora* R. Br.
3. *Tylophora indica* (Burm. F.) Merr.

BOMBACACEAE

4. *Bombax ceiba* L.

CAESALPINIOIDEAE

5. *Bauhinia purpurea* L. var. *purpurea*
6. *B. tomentosa* L.
7. *Brownea grandiceps* Jacq.
8. *Caesalpinia bonduc* L. emend. Dandy & Excll.
9. *C. pulcherrima* (L.) Swartz.
10. *Cassia absus* L.
11. *C. alata* L.
12. *C. auriculata* L.
13. *C. fistula* L.
14. *C. floribunda* Cav.
15. *C. glauca* var. *glauca* Lamk.
16. *C. glauca* var. *suffruticosa* Prain.
17. *C. grandis* L.
18. *C. hirusta* L.
19. *C. javanica* L.
20. *C. mimosoides* L.
21. *C. obtusa Roxb.*
22. *C. obtusifolia* L.
23. *C. occidentalis* L.
24. *C. pumila* Lamk.
25. *C. roxburghii* DC.
26. *C. senna* L.
27. *C. siamea* Lamk.
28. *C. sophera* L.
29. *C. spectabilis* DC.
30. *C. tora* L.
31. *Cynometra ramiflora* L. var. *mimosoides* Baker.
32. *Delonix elata* Gamble.
33. *D. regia* (Bojer ex Hook.) Rafin.
34. *Gleditsia* sp.
35. *Hardwickia binata* Roxb.
36. *Humboldtia brunonis* Wall.
37. *Parkinsonia aculeata* L.
38. *Peltophorum pterocarpa* (DC.) Baker.
39. *Pterolobium hexapetalum* (Roth.) Sant & Wagh
40. *Saraca asoca* (Roxb.) de Wilde.
41. *Tamarindus indica* L.
42. *Wagatea spicata* Dalzell

CAPPARIDACEAE

43. *Cleome aspera* Koen.
44. *C. chelidonii* L.
45. *C. felina* L.
46. *C. gynandra* L.
47. *C. monophylla* L.
48. *C. tenella* L.
49. *C. viscosa* L.

COMPOSITAE

50. *Acanthospermum hispidum* DC.
51. *Ageratum conyzoides* L.
52. *Caesulia axillaris* Roxb.
53. *Carthamus tinctorius* L.
54. *Eclipta prostrata* L.
55. *Lagascea mollis* Cav.
56. *Parthenium hysterophorus* L.
57. *Sonchus oleraceus* L.
58. *Tridax procumbens* L.
59. *Vernonia rinerea* (L.) Less.

CUCURBITACEAE

60. *Citrulus lanatus* (Thumb.) Mansb.
61. *Coccinia grandis* (L.) Voigt.
62. *Cucumis melo* L.
63. *C. pubescens* Willd.
64. *C. sativus* L.
65. *Cucurbita maxima* Duch.
66. *Lagenaria siceraria* (Molina) Standley
67. *Luffa cylindrica* (L.) M. Roem.
68. *Momordica charantia* L.
69. *M. dioica* Roxb.

EUPHORBIACEAE

70. *Acalypha indica* L.
71. *Croton bonplandianum* Baillon.
72. *Euphorbia geniculata* Orteg.
73. *E. heterophylla* L.
74. *E. hirta* L.
75. *E. pulcherrima* Willd.
76. *Jatropha gossypifolia* L.
77. *Ricinus communis* L.

GRAMINAEAE

78. *Andropogon pumilus* Roxb.
79. *Cymbopogon citratus* (DC.) Stapf.
80. *C. martinii* Wats.
81. *Cynodon dactylon* (L.) Pers.
82. *Digitaria adscendens* (HBK) Henr.
83. *Eragrostiella brachyphylla* (Stapf.) Bor.
84. *Eragrostis gangeticus* (Roxb.) Steud.
85. *E. viscosa* (Retz.) Trin.
86. *Eriochloa procera* (Retz.) Hubbard.
87. *Oryza alta* Sw.
88. *O. australiensis* Domin.
89. *O. barthii* Chev.
90. *O. brachyanaha* Chev.
91. *O. breviligulata* Chev.
92. *O. glaberrima* Steud.
93. *O. gandiglumis* Prod.
94. *O. latifolia* Desv.

95. *O. malampuzhaensis* Kri & Chand.
96. *O. minuta* F. & C.
97. *O. officinalis* Wall.
98. *O. perennis* Moench.
99. *O. perrieri* Cam.
100. *O. punctata* Kot. ex. Steud.
101. *O. sativa* L.
102. *O. schweinfurthiana* Prod.
103. *Panicum repens* L.
104. *Paspalum disticum* L.
105. *Saccharum officinarum* L.
106. *Sorghum bicolor* Moench.
107. *Triticum vulgare* Willw.
108. *Zea mays* L.

LABIATEAE

109. *Ocimum sanctum* L.
110. *Salvia splendens* Ker-Gawl.

MALVACEAE

111. *Abelmoschus esculentus* (L.) Moench.
112. *Abutilon indicum* (L.) Sweet
113. *Althea rosea* Cav.
114. *Gossipium herbacium* L.
115. *Hibiscus cannabinus* L.
116. *H. hirtus* L.
117. *H. rosa-sinensis* L.
118. *Malvaviscus arboreus* Cav.
119. *Pavonia zeylanica* (L.) Cav.
120. *Sida acuta* Burm. F.
121. *S. cordifolia* G. Don.

MIMOSOIDEAE

122. *Acacia arabica* (Lmk). Willd.
123. *A. auriculiformis* A. cunn.
124. *A. leucophloea* (Roxb.) Willd.
125. *Adenanthera pavonina* L.
126. *Albizia amara* Boivin
127. *A. lebbeck* (L.) Willd.
128. *Calliandra haematocephala* Hassk.
129. *Desmanthus virgatus* Willd.
130. *Dichrostachys cinerea* (L.) Wt. & Arn.
131. *Leucaena leucocephala* (Lamk.) Wit.
132. *Mimosa barberi* Lamk.
133. *M. hamata* Willd.
134. *M. praniana* Gamble
135. *M. pudica* L.
136. *M. rubicaulis* Lamk.
137. *Neptunia oleracea* Lour.
138. *N. triquetra* Benth.
139. *Parkia biglandulosa* W. & A.
140. *Pithecellobium dulce* (Roxb.) Benth.
141. *Prosopis cineraria* (L.) Durce
142. *P. juliflora* (Swartz.) DC.
143. *Samanea saman* (Jacq.) Merr.
144. *Xylia xylocarpa* Taub.

PAPILIONOIDEAE

145. *Abrus precatorius* L.
146. *Aeschynomene indica* L.
147. *Alysicarpus hamosus* Edgew.
148. *A. monilifer* (L.) DC.
149. *A. rugosus* (Willd.) DC.
150. *Arachis hypogea* L.
151. *Atylosia scarabaeoides* (L.) Benth.
152. *Butea monosperma* (Lam.) Taub.
153. *Cajanus cajan* (L.) Millsp.
154. *Canavalia ensiformis* (L.) DC.
155. *Cicer arietinum* L.
156. *Clitoria ternatea* L.
157. *Crotalaria biflora* L.
158. *C. laburnifolia* L.
159. *C. pusilla* L.
160. *C. ramosissima* Roxb.
161. *C. verrucosa* L.
162. *Dalbergia latifolia* Roxb.
163. *D. sissoo* Roxb.
164. *Derris scandens* (Roxb.) Benth.
165. *Desmodium triflorum* (L.) DC.
166. *Dolichos lablab* L.
167. *Erythrina blakei* Hort. Ex. Parker
168. *E. orientalis* (L.) Murr.
169. *E. suberosa* Roxb.
170. *Heylandia latebrosa* DC.
171. *Medicago sativa* L.
172. *Melilotus alba* Desr.
173. *M. indica* All.
174. *Mucuna pruriens* (L.) DC.
175. *Ormosia travancorica* Bedd.
176. *Phaseolus aconitifolius* Jacq.
177. *P. trilobus* Ait.
178. *Pongamia pinnata* (L.) Pierre.
179. *Pterocarpus marsupium* Roxb.
180. *P. santalinus* L.
181. *Rhynchosia aurea* DC.
182. *R. minima* Benth.
183. *Shuteria vestita* Wight. & Arn.
184. *Sophora glauca* Lesch.
185. *Stylosanthes fruticosa* (Retz.) Alston
186. *Trigonella foenum-graecum* L.
187. *Vigna cylindrica* (L.) Skeels.
188. *Zornia diphylla* (L.) Pers.
189. *Z. gibbosa* Span.

PORTULACACEAE

190. *Portulaca grandiflora* Hook.
191. *P. oleracea* L. var. *oleracea*.
192. *P. pilosa* L.
193. *P. quadrifida* L.

194. *P. suffruticosa* Wall. Ex W. & A.
195. *P. tuberosa* Roxb.
196. *P. wightiana* Wall. Ex W. & A.
197. *Portulacaria afra*. Jacq.
198. *Talinum triangulare* (Forsks.) Aschers Ex Schweinf.

SOLANACEAE

199. *Solanum nigrum* L.

STERCULIACEAE

200. *Dombeya cayeuxii* Hort.
201. *Guazuma ulmifolia* Lamk.
202. *Waltheria americana* L.

TILIACEAE

203. *Corchorus tridens* L.
204. *C. trilocularis* L.
205. *C. urticifolius* W. & A.
206. *Muntingia calabura* L.
207. *Triumfetta pentandra* A. Rich.

UMBELLIFEREAE

208. *Centella asciatica* (L.) Urban.
209. *Coriandrum sativum* L.

small, the peels represented the entire leaf surface. These were stained with 1 per cent aniline blue in lactophenol, mounted in glycerine (Ramayya & Rajagopal, 1968), and observed at 200 magnification. Herbarium specimens and peel-slides studied are deposited in the Plant Anatomy and Taxonomy Laboratory, Osmania University, Hyderabad, India.

OBSERVATION

The data have been analysed under two sub-heads, viz., I. structural characters and II. distribution characters of epidermal cells.

I. Structural Characters of Epidermal Cells

The epidermal cells of the angiosperms show considerable variation in shape, anticlinal and periclinal walls, cell contents and sculpturing. The variation known under each of these characters is summarised as below:

A. *Shape*

1. Polygonal : Cell having more than four sides, isodiametric (with nearly equal *diameters; Fig. 1) or anisodiametric or non-linear (cells in which the longest diameter is lesser than twice its smallest diameter; Fig. 2) and linear (the longest diameter is more than twice the smallest diameter; Fig. 3).
2. Rectangular : Cells rectangular in shape, linear (Fig. 5). or non-linear (Fig. 4).
3. Squarish : Cells square- like (Fig. 6).
4. Trapezoidal : Cells trapezium-like with two parallel sides, linear (Fig. 8) or non-linear (Fig. 7).
5. Trapizial : Cells quadrilateral with no parallel sides, linear (Fig. 10) or non-linear (Fig. 9).
6. Rhomboidal : Cells rhomboid in shape or like an oblique angled parallelograms with opposite or lateral sides nearly equal, linear (Fig. 13) or non-linear (Figs 11 & 12).
7. Triangular: Cells with three sides, linear (Fig. 15) or non-linear (Fig. 14).

*Since cells are of varied shapes, it is impracticable to locate their geometrical centre and measure the diameter. Here the 'diameter' is, therefore, applied to lines which pass through the hypothetical centre of the cell figure and which may either connect two opposite angles, or an angle and its opposite side, or two opposite sides.

8. Fusiform : Cells spindle-shaped or broadened at the middle and progressively tapering towards the ends, linear (Fig. 16) or non-linear (Fig. 17).
9. Spathulate: Cells having a broad round end, with attenuating base, linear or non-linear (Fig. 18).
10. Polygonal-rhomboidal : Similar to rhomboidal cells but with more than four sides (Fig. 19).
11. Dumb-bell-shaped : Cells having the shape of a dumb-bell (Fig. 20).
12. Circular : Cells circular in shape (Fig. 21).

Epidermal cells of linear form are often found on elongated organs, whereas others characterise laminar organs (Esau, 1965); rarely however the reverse condition is also met with.

B. *Characters of anticlinal walls*

1. Straight : Walls without a bend, angle or curve (Figs 22, 23).
2. Curved : Walls with a continuous bend (Figs 23-25).
3. Wavy : Walls with undulations (curving in opposite directions, curves being shallow (Figs 25-27).
4. Sinuate : Walls strongly or distinctly wavy, forming varied types of sinuses viz., 'U', 'V', Omega, delta etc. (Figs 27-35).
5. Thin : When the anticlinal walls are thin (Fig. 1).
6. Thick : When the anticlinal walls are thick without pits (Fig. 3).
7. Pitted : When the anticlinal walls are thick and pitted (Fig. 8).

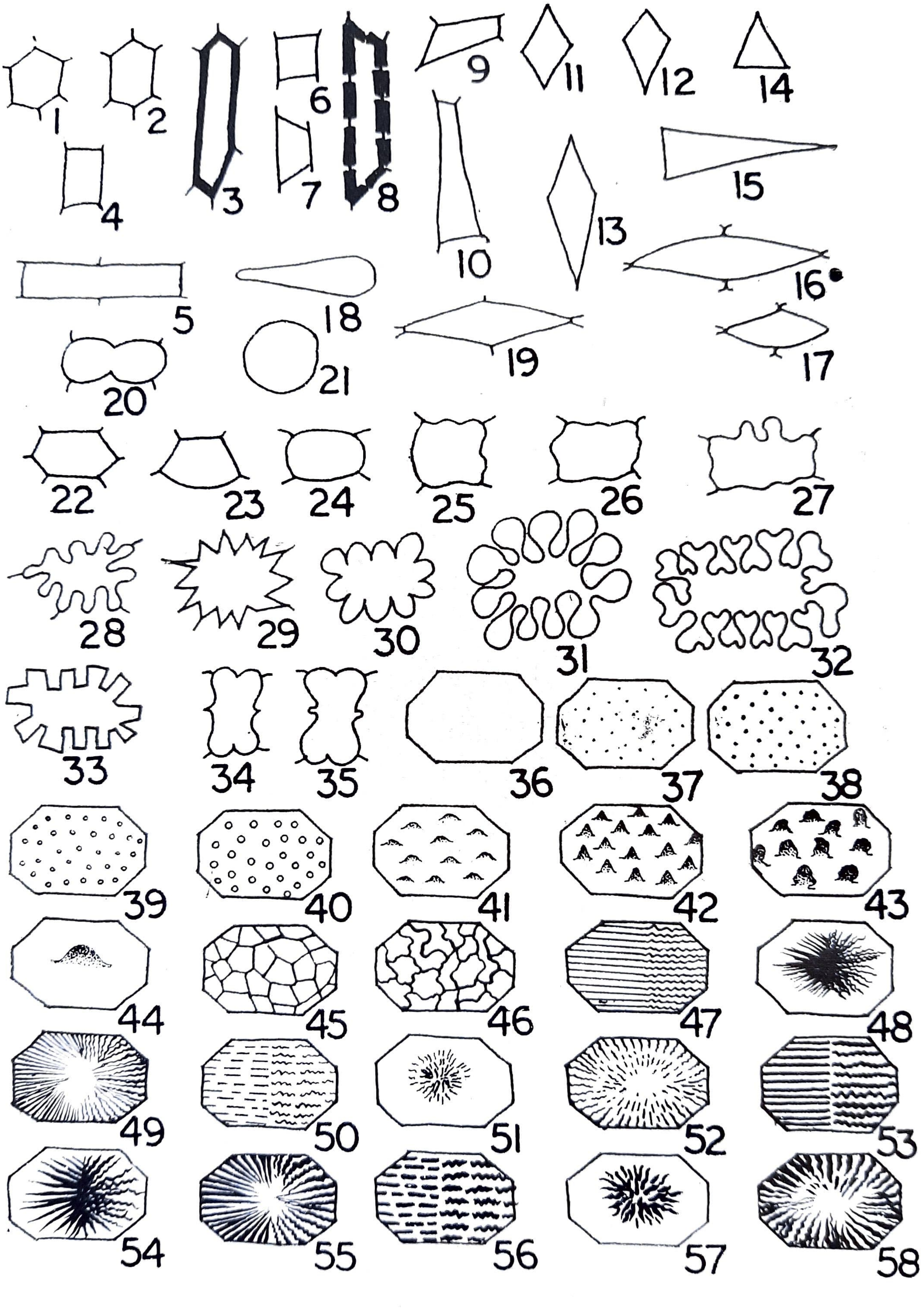
C. *Characters of outer wall*

1. Flat : When the outer wall of the cell is flat (as in *Talinum triangulare* leaf).
2. Concave : When the outer wall of the cell is concave (as in *Ficus heterophylla* L. Leaf adaxial).
3. Convex : When the outer wall of the cell is convex (as in *Cocculus hirsutus* (L.) Diels. leaf)
4. Tuberculate : When the outer wall of the cell is tuberculate (as in *Cynodon dactylon* leaf).
5. Papillate : When the outer wall of the cell is papillate (as in *Indigofera uniflora* Ham. leaf).

D. *Cytoplasmic contents*

1. Dense : When the cytoplasm is abundant (as in *Portulaca tuberosa* stamen).
2. Scanty : When the cytoplasm is scanty (as in *P. tuberosa* stem).
3. Absent : When the cytoplasm is totally lacking (as in *Cassia roxburghii* leaf).
4. Translucent : When the cytoplasm is transparent (as in *Talinum triangulare* sepal adaxial).
5. Chlorophyllous: When the cells contain chloroplasts (as in *Portulaca oleracea* leaf).
6. Achlorophyllous: When the cells are devoid of chloroplasts (as in *Samanea saman* leaf).

Besides the above, the cytoplasm may contain inulin crystals, starch grains, calcium oxalate and calcium carbonate crystals, silica bodies, mucilage, resins, pigments etc. In many plants, however, certain epidermal cells become idioblast and distinctive from the neighbouring elements possessing the above inclusions. Such epidermal cell elements, the authors consider to result from a high degree of speciali-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sation and hence, require separate treatment which would be taken up separately elsewhere.

E. *Surface of the cells*

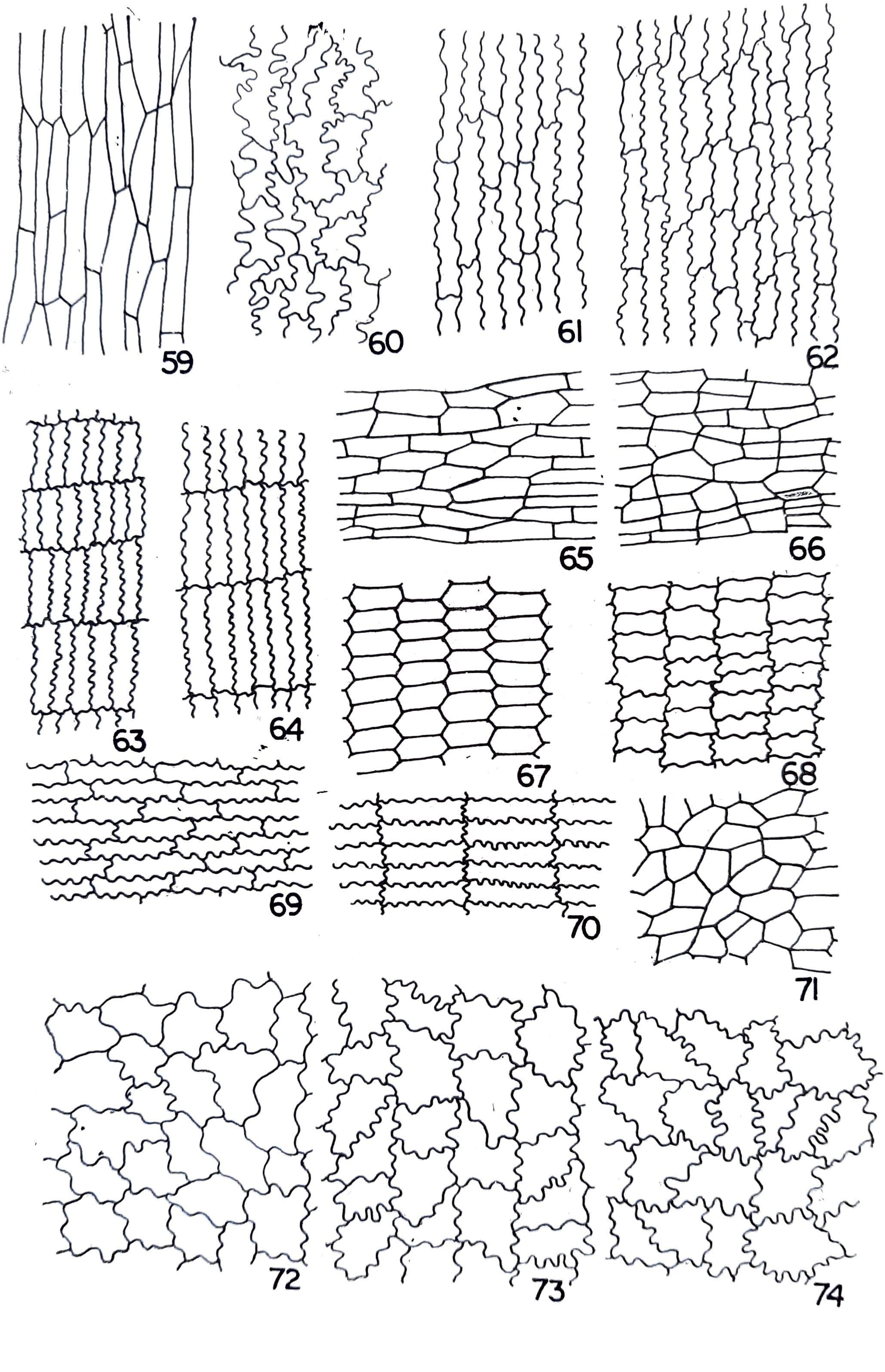
The upper surface of the outer wall of an epidermal cell is often characterised by different patterns of cuticular ornamentation, which being usually of stable nature are of identification value. So far, the following patterns are recognisable in the angiosperms; the terms for describing them have been adapted from JACKSON (1928) and STEARN (1966).

1. Smooth : Free from any sculpturing (Fig. 36).
2. Puncticulate : Minutely punctate, the surface appearing almost smooth (Fig. 37).
3. Punctate : Marked with dots, looking like pencil-marks, variously scattered (Fig. 38).

Figs 1-21. Diagrammatic representation of epidermal cell shapes. 1. Polygonal isodiametric-*Portulaca oleracea* var. *oleracea* ovary basal half. 2. Polygonal anisodiametric-*Cassia siamea* leaf adaxial. 3. Polygonal linear-*portulaca tuberosa* ovary basal half. 4. Rectangular non-linear-*Cassia siamea* leaf adaxial. 5. Rectangular linear-*Cynodon dactylon* leaf adaxial. 6. Squarish-*Portulaca quadrifida* petiole adaxial. 7. Trapezoidal non-linear-*Portulaca tuberosa* ovary basal half. 8. Trapezoidal linear-*Portulaca oleracea* var. *oleracea* ovary upper half. 9. Trapezial non-linear-*Talinum triangulare* petal adaxial proximal part. 10. Trapezial linear-*Talinum triangulare* stem. 11, 12. Rhomboid non-linear-*Elaeis guineesis* Jacq. leaf adaxial. 13. Rhomboid linear-*Areca catechu* L. leaf adaxial. 14. Triangular non-linear-*Albizia lebbeck* leaf adaxial.- 15. Triangular linear-*Cassia obtusa* leaf adaxial. 16, 17. Fusiform linear and non-linear respectively-*Portulaca quadrifida* stem. 18. Spathulate-*Calamagrostis epigejos* Roth. leaf adaxial 19. Polygonal rhomboidal-*Areca catechu* leaf adaxial. 20. Dumb-bell-shaped-*Oryza perennis* leaf adaxial. 21. Circular-*Sophora glauca* leaf adaxial.

Figs 22-35. Diagrammatic representation of the aticlinal walls of epidermal cells. 22. Straight-*Cassia siamea* leaf adaxial. 23-25. Curved-*Cassia auriculata* leaf adaxial. 25-27. Wavy-*Cassia absus* leaf adaxial. 27, 28. Sinuate, sinuses 'U'-shaped-*Portulaca whitiana* leaf adaxial., 29. Sinuate, sinuses 'V'-shaped-*Ocimum sanctum* leaf adaxial. 30. Sinuate, sinuses 'W'-shaped *Portulaca quadrifida* petal abaxial. 31. Sinuate, sinuses *Protulaca quadrifida* sepal a daxial. 32. Sinuate, sinuses, *Portulaca grandiflora* sepal adaxial. 33. Sinuate, sinuses *Portulaca pilosa* petal abaxial. 34. Sinuate, sinuses '⌒⌒'-shaped-*Oryza austrailiensis* leaf adaxial. 35. Sinuate, sinuses '⌒⌒''-shaped-*Oryza minuta* leaf adaxial.

Figs 36-58. Diagrammatic representation of epidermal cell surfaces. 36. Smooth-*Talinum triangulare* leaf adaxial. 37. Puncticulate-*Oryza sativa* stem. 38. Punctate-*oryza officinalis* leaf adaxial. 39. Granulate-*oryza punctata* leaf adaxial. 40. Tuberculate-*Cynodon dactylon* leaf adaxial. 41. Pustulate-*Gibasis schiedeana* (Kunth.) D. R. Hunt. leaf adaxial. 42. Spinous-*panicum hians* Ell. palea apex. 43. Verrucose-*Panicum amarum* Ell. palea apex. 44. Papillate-*Samanea saman* leaf adaxial. 45. Reticulate-*Murdannia zeylanica* Bru. leaf adaxial. 46. Ruminate-*Aloe aristata* Haw. leaf adaxial. Figs 47-49. Variation in lineate cell surface. 47. Straight and wavy, parallel-*Croton bonplandianum* Baillon and *Cannabis sativa* L. leaf abaxial. 48. Straight and wavy, divergent-*Haworthia coarctata* Haw. 49. Straight and wavy, convergent (Hypothetical). Figs 50-52. Variation in lineolate cell surface. 50. Straight and wavy, parallel-*Murdannia graminea* Bru. and *Raphiodon echinus* S chawer. 51. Straight and wavy, divergent-*Haworthia coarctata* Haw. sub. sp. *adelaidensis* (Von Pollen.) Bayer. 52. Straight and wavy, convergent (Hypothetical). Figs 53-55. Variation in striate cell surface. 53. Straight and wavy, parallel *Jatropha pandurifolia* Andr. leaf costal cells and *Bupleurum tenue* Buch-Ham. Ex. D. Don. leaf. 54. Straight and wavy, divergent-*Vicia sativa* seed. 55. Straight and wavy, convergent-*Plumeria rubra* L. var. *acutifolia* (Poir.) Woodson leaf adaxial. Figs 56-58. Variation in striolate cell surface. 56. Straight and wavy, parallel-*Jatropha pandurifolia* leaf adaxial and *Pancratum* sp. 57. Straight and wavy, divergent-*Gasteria Cheilophylla* Bak. 58. Straight and wavy, convergent (Hypothetical).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4. Granulate : Characterised by fine granules of assorted sizes, nearly isodiametric and smaller than tubercles (Fig. 39).
5. Tuberculate : With elevations slightly longer than broad and round apex (Fig. 40).
6. Pustulate : With elevations broader than long and obtuse apex (Fig. 41).
7. Spinous : Covered with small pointed projections of isodiametric to somewhat anisodiametric types (Fig. 42).
8. Verrucose : Characterised by projections of irregular shape, mostly longer than broad (Fig. 43).
9. Reticulate (Alveolate) : Surface with net-work like sculpturing, with the side of alveoli straight (Fig. 45).
10. Ruminate : Surface with a net-work like sculpturing, with the sides of alveoli undulate (Fig. 46).
11. Papillate : Consisting of a single small nipple-like process or projection (Fig. 44) which may also be variously ornamented like the epidermal cells.
12. Lineate : Marked with fine lines; lines straight or wavy, parallel, convergent or divergent (Figs 47-49).
13. Lineolate : Marked with fine broken lines; lines straight or wavy, parallel, convergent or divergent (Figs 50-52).
14. Striate : Characterised by furrows alternating with ridges, the ridges wider than the lines of lineate condition; the striae straight, wavy, parallel, convergent or divergent (Figs 53-55).
15. Striolate : Characterised with broken striations; the striolae may be straight or wavy, parallel, convergent or divergent (Figs 56-58).

II. Distribution Characters of Epidermal Cells

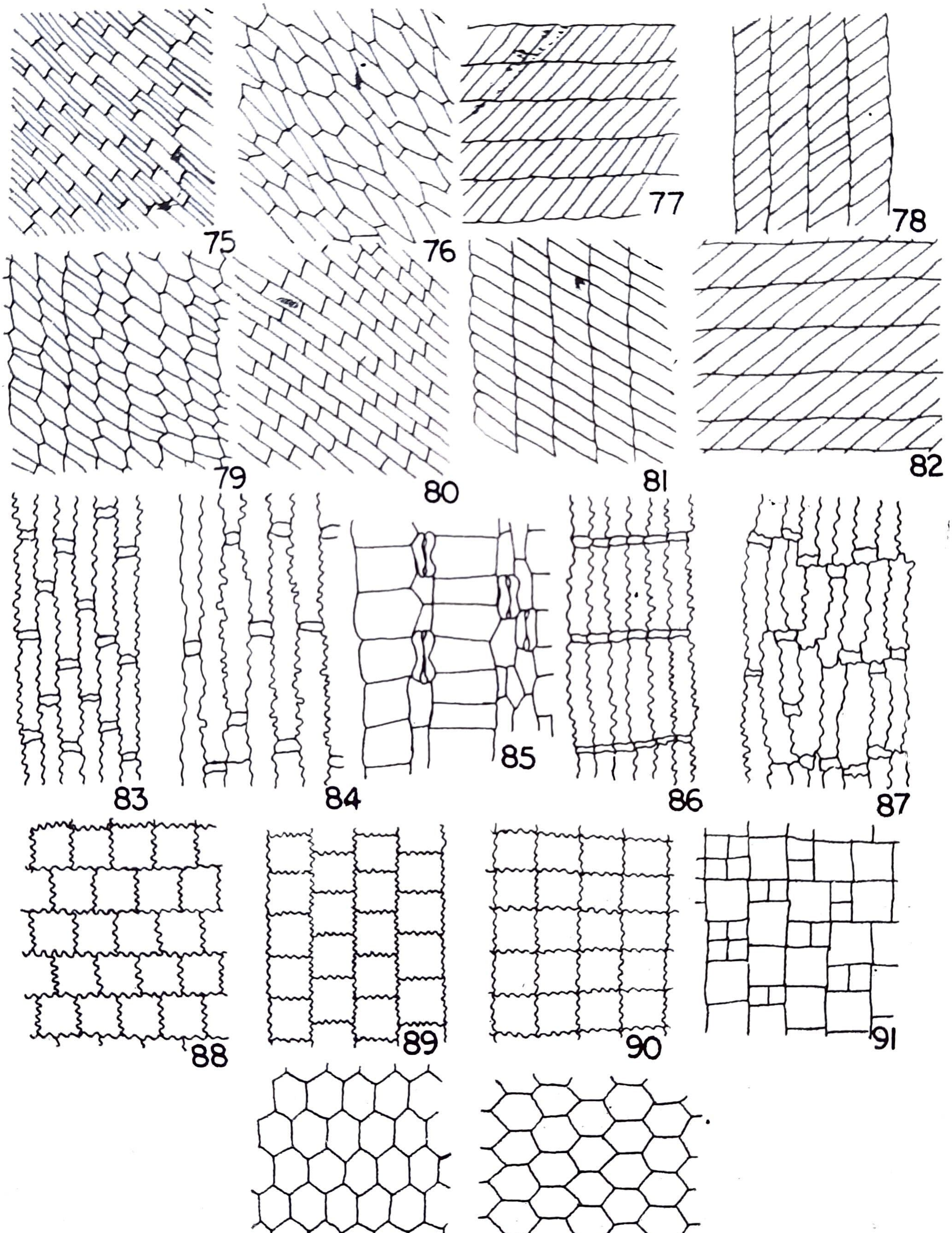
Epidermal cell distribution can be resolved into two components viz., orientation and arrangement. Particulars of the two aspects are as given below :

A. *Orientation*

Denotes the direction,in which the epidermal cell elements are oriented with reference to the axis of plant part on which they occur. These are as follows :

1. Parallely oriented : When the cells are oriented parallely to the long axis of the plant part (Figs 59-64, 83-87).
2. Transversely oriented : When the cells are oriented transverse to the long axis of the plant part (Figs 65-70, 83-87).

Figs 59-93. Diagrammatic representation of epidermal cells orientation and arrangement. Figs 59-64. Cells parallely oriented; 59, 60. Cells parallely oriented and arranged irregularly-*Talinum triangulare* petal base and sepal abaxial respectively. 61,62. Cells parallely oriented and arranged in vertical rows-*Oryza sativa* stem. 63. Cells parallely oriented and arranged in transverse rows (Hypothetical). 64. Cells parallely oriented and arranged in vertical and transverse rows (Hypothetical). Figs 65-70. Cells transversely oriented. 65,66. Cells arranged irregularly-*Portulaca pilosa* peduncle. 67,68. Cells arranged in vertical rows-*Portulaca suffruticosa* petiole. 69. Arranged in transverse rows (Hypothetical). 70. Arranged in vertical and transverse rows (Hypothetical). Figs 71-74. Cells variously oriented. 71,72. Cells arranged irregularly-*Portulaca quadrifida* leaf abaxial. 73. Cells arranged in vertical rows-*Portulaca tuberosa* leaf abaxial. 74. Cells arranged in transverse rows (Hypothetical).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3. Obliquely oriented : When the cells are oriented obliquely to the long **axis** of the plant part (Figs 75-82).
4. Variously oriented : When the cells are oriented in different **directions** to the long axis of the plant part (Figs 71-74).

B. *Arrangement*

Denotes the organisation of masses of epidermal cell elements with reference to the long axis of the plant part. They are as follows:

1. Arranged irregularly : When the cells are not arranged in specific direction with reference to the long axis of the organ (Figs 59, 60, 65, 66, 71, 72, 75, 76, 87, 91).
2. Arranged in vertical rows : When the cells are arranged in vertical rows, parallel to the long axis of the organ (Figs 61, 62, 67, 68, 73, 78, 79, 83, 85, 89).
3. Arranged in transverse rows : When the cells are arranged in transverse rows with reference to the long axis of the organ (Figs 63, 69, 74, 77, 88).
4. Arranged in oblique rows : When the cells are arranged in oblique rows with reference to the long axis of the organ (Fig. 80).
5. Arranged in vertical and transverse rows : When the cells are arranged in vertical as well as transverse rows with reference to the long axis of the organ (Figs 64, 70, 86 90).
6. Arranged in oblique and transverse rows : When the cells are arranged in oblique as well as transverse rows with reference to the long axis of the organ (Figs 82, 92).
7. Arranged in oblique and vertical rows : When the cells are arranged in oblique as well as vertical rows with reference to the long axis of the organ (Figs 81, 93).

PATTERNS OF DISTRIBUTION

Epidermal cells show different patterns of distribution due to differences in varied combinations of their orientation and arrangement.

Analysis of the epidermal cell distribution in different parts in the species studied and also of the observations available in the previous literature shows that the distribution patterns are closely related to the type of epidermal cells whether they are predominantly anisodiametrical (linear and non-linear) or isodiametrical. In the former case, the cells differ not only in their arrangement but also in orientation. On the other hand the latter cells differ only in their arrangement, and not in orientation

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Figs 75-82. Cells obliquely oriented. 75,76. Cells arranged irregularly-*Acrocomia aculeata* Lodd. Ex. Mart. Leaf. 77. Cells arranged in transverse rows (Hypothetical) 78, 79. Cells arranged in vertical rows-*Stevensonia borsigiana* Bailey leaf adaxial. 80. Cells arranged in oblique rows (Hypothetical). 81 Cells arranged in oblique and vertical rows-*Orania philippinensis* Scheff. Ex. Becc. leaf adaxial. 82. Cells. arranged in oblique and transverse rows (Hypothetical). Figs 83-87. Cells parallely and transversely oriented. 83-85. Arranged in vertical rows-*Oryza sativa* and *Restio leptocarpoides* Benth. Culm. 86. Arranged in vertical and transverse rows (Hypothetical). 87. Arranged irregularly (Hypothetical). Figs 88-91. Arrangement of isodiametric cells. 88. Arranged in trnsverse rows-*Haworthia reinwa dtii* Haw. f. *Kaffira driftensis* (smith) Bayer. 89. Arranged in vertical rows *Haworthia coarctata* Haw. Sub. sp. *Coarctata* var. *Grenii* (Baker) Bayer. leaf. 90. Arranged in vertical and transverse rows (Hypothetical). 91. Arranged irregularly-*Portulaca oleracea* var. *oleracea* ovary basal half. 92. Arranged in transverse and oblique rows-*Gasteria Lutzii* × *Aloe aristata*. leaf. 93. Arranged in vertical and oblique rows-*Haworthia coarctata* leaf.

because of isodiametry. Accordingly, in the following, the distribution patterns of epidermal cells are described with reference to the two cells types.

I. Distribution Patterns of Anisodiametric Type of Epidermal Cells

The following include patterns which have been so far recorded in and also those hypothetically suggestive and likely to occur. Further, these patterns occur in epidermal areas where all or majority of the epidermal cells are anisodiametric.

i. Cells parallelly oriented

Pattern-1. Arranged irregularly (Figs 59, 60).
Pattern-2. Arranged in vertical rows (Figs 61, 62).
Pattern-3. Arranged in transverse rows (Fig. 63).
Pattern-4. Arranged in vertical and transverse rows (Fig. 64).

ii. Cells transversely oriented

Pattern-5. Arranged irregularly (Figs 65, 66).
Pattern-6. Arranged in vertical rows (Figs 67, 68).
Pattern-7. Arranged in transverse rows (Fig. 69).
Pattern-8. Arranged in vertical and transverse rows (Fig. 70).

iii. Cells variously oriented

Pattern-9. Arranged irregularly (Figs 71, 72).
Pattern-10. Arranged in vertical rows (Fig. 73).
Pattern-11. Arranged in transverse rows (Fig. 74).

iv. Cells obliquely oriented

Pattern-12. Arranged irregularly (Figs 75, 76).
Pattern-13. Arranged in vertical rows (Figs 78, 79).
Pattern-14. Arranged in transverse rows (Fig. 77).
Pattern-15. Arranged in oblique rows (Fig. 80).
Pattern-16. Arranged in oblique and transverse rows (Fig. 82).
Pattern-17. Arranged in oblique and vertical rows (Fig. 81).

v. Cells vertically and transversely oriented

Pattern-18. Arranged irregularly (Fig. 87).
Pattern-19. Arranged in vertical rows (Figs 83-85).
Pattern-20. Arranged in vertical and transverse rows (Fig. 86).

II. Distribution Patterns of Isodiametric Type of Epidermal Cells

The patterns described here as in the case of anisodiametric epidermal cells include those which have been so far observed and also those hypothesised and likely to occur. Further, these patterns are applicable to those epidermal areas where all or majority of the epidermal cells are isodiametric.

Pattern-1. Arranged in transverse rows (Fig. 88).
Pattern-2. Arranged in vertical rows (Fig. 89).
Pattern-3. Arranged in vertical and transverse rows (Fig. 90).
Pattern-4. Arranged irregularly (Fig. 91).

Pattern-5. Arranged in transverse and oblique rows (Fig. 92).

Pattern-6. Arranged in vertical and oblique rows (Fig. 93).

Distribution patterns often differ from organ to organ in a given plant and hence, require to be studied in relation to each part. Further, unlike the axiate parts, the appendicular ones have two surfaces, viz., the adaxial and abaxial, their epidermal cell distribution patterns necessitating studies on both surfaces. In many species even in a single surface, whether of the axiate or appendicular structures, differentiation may occur into sub-areas such as the inter-stitial and veinular regions in the appendicular surfaces. Similarly in the axiate parts differentiation may take place into nodal and internodal areas, the latter again into sub-areas as ridges and furrows. In any case, distribution, be it at any level, if it is consistently distinctive and hence of identification value, it needs to be separately studied.

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