Fig. 1.1 Some mechanical systems in monocotyledons. (a) A fleshy leaf of *Gasteria*; note lack of sclerenchyma in the section (b). (c) A mesic monocotyledon, C–D shows one type of sclerenchyma arrangement in leaf TS; E–F shows three of the main types of sclerenchyma arrangements in the stem TS; G–H shows a typical root section in which most strength is concentrated in the centre. en, endodermis; gt, ground tissue, which may be lignified.

Fig. 1.2 Some mechanical systems in dicotyledons. A schematic plant with position of sections indicated. Liquid pressure occurs in turgid cells through the plant. Collenchyma is often conspicuous in actively extending regions and petioles. Sclerechyma fibres are most abundant in parts that have ceased main extension growth. Xylem elements with thick walls have some mechanical function in young plants and give a great deal of support in most secondarily thickened plants.

Fig. 1.3 *Fagus sylvatica* leaf (TS, ×48), showing one row of vascular bundles, with the xylem poles directed towards the adaxial surface. Note the marginal sclerenchyma strands and the difference in size between adaxial and abaxial epidermal cells. Each small vascular bundle has a parenchyma sheath; in larger bundles sclerenchyma caps interrupt the parenchyma sheath.

Fig. 2.1 Vegetative meristems. (a) Low-power diagram LS of *Rhododendron* apex, ×15. (b) Detail of (a), ×218. The second layer may be 'tunica' but has some periclinal division, so that in (c), *Syringa* ×218. (d) *Equisetum* ×218 has an apical cell and not a group of meristematic cells.

Fig. 2.2 *Codonanthe*: (a) low-power diagram of details of apex of shoot shown in (b). Notice the very early division of cells in the adaxial epidermis of the leaves, leading to the formation of a multiple epidermis. (b) ×248.

Fig. 2.3 *Cedrus* shoot apex, LS. Arrow = leaf buttress. C ×100.

Fig. 2.4 (a) Generalized monocotyledon root, diagram to show location of various zones. Root apex, LS, in *Allium* sp.; (b) low-power diagram to show location of various cell zones in (c) (×109); a, apical meristem; c, column; ca, calyptragon; ce, central cylinder; ci, central cylinder initials; co, cortex; coi, cortex initials; pr, protoderm initials; r, root cap.

Fig. 2.5 Endogenous development of a lateral root, in, LS, cortex; ca, small cavity ahead of developing root formed by lysis of cortical cells; en, endodermis; l, lateral root; p, pericycle; ph, phloem; x, xylem.

Fig. 2.6 Diagram of fusiform cambial initials (f) and ray initials (r).

Fig. 2.7 *Dianthus* (carnation) cutting. Adventitious roots will develop from the split sides. n, node.

Fig. 2.8 *Ribes nigrum*, TS of outer part of stem to show deep-seated cork cambium, ×218. ck, cork; cu, cuticle; p, phellogen; pd, phelloderm. Note cluster crystals in cortical cells.

Fig. 2.9 Diagram of TS of conifer log showing resumed continuity of growth rings after lateral branch has been cut off.

Fig. 2.10 Chip bud graft. (a) Chip with bud; (b) stock prepared; (c) chip inserted behind small flap of bark (f), ready for taping.

Fig. 2.11 Twigs grafted across a damaged area of bark on a tree trunk.

Fig. 3.1 *Alnus glutinosa*: SEM photograph of secondary xylem showing transverse and tangential longitudinal faces. af, fibres in axial system of cells; av, vessel of axial system; p, perforation plate (scalariform); r, uniseriate ray of radial system. ×100.

Fig. 3.2 (a) Transverse, (b) radial longitudinal and (c) tangential views of the wood of *Alnus nepalensis*. Note the narrow-diameter vessels. These have inclined compound scalariform-reticulate perforation plates. The vessels are interspersed with narrow tracheids and parenchymatous elements. Rays are of variable length and uniseriate, a, ×70; b and c, ×250.

Fig. 3.3 (a) Transverse, (b) radial longitudinal and (c) tangential longitudinal views of the wood of *Pinus sylvestris*. Rays are variable, from one to many cells high and of variable width. Wider rays may be associated with resin canals. a, ×75; b and c, ×250.

Fig. 3.4 Some types of cross-field pits in conifers. (a) Piceoid, e.g. *Picea*, *Larix*. (b) Cupressoid, found in most Cupressaceae and Taxus. (c) Taxodioid, e.g. *Taxodiaceae*, *Abies*, *Cedrus*, some *Pinus*. (d) Diagram showing location of cross-field pits (c) where ray and tracheid walls are adjacent. (e) Some *Pinus* spp. have large ‘window’ pits, r, ray; t, tracheid.

Fig. 3.5 A range of vessel element perforation plates and wall pitting. (a) *Camellia sinensis* scalariform. (b) *Liriodendron tulipfera*, scalariform; pits opposite. (c) *Sambucus nigra*, simple plate, pits alternate. (d) *Euphorbia splendens*, simple plate, pits alternate. (e) *Scirpus verna*, scalariform plate, pits opposite (from primary xylem). All ×218.

Fig. 3.6 *Tilia europaea*, LS, tertiary spirals on vessel element wall. SEM, ×3000.

Fig. 3.7 *Eckhorda pyramidalis*, wood TS; note the vessel, the thin-walled fibres and abundant parenchyma. ×200.

Fig. 3.8 *Gnetum officinale* wood TS; note the numerous thick-walled fibres and the scattered parenchyma. ×200.

Fig. 3.9 *Quercus robur*, wood TS and TLS, SEM. Note wide spring-formed vessels (s) and narrow later-formed vessels (n). Numerous uniseriate rays can be seen (a). Small parenchyma cells of the axial system occur in more or less tangential bands among the fibres (f). A growth ring (g) is shown, as is vasicentric parenchyma (v). ×60.

Fig. 3.10 Some ray types in TLS. (a) *Alnus glutinosa*, uniseriate, homocellular, all cells of procumbent type. (b) *Swietenia mahagoni*, multisieriate, heterocellular, with upright cells at margins and procumbent cells between. (c) *Sambucus nigra*, biseriate, with tall uniseriate portions, heterocellular. (d) *Muusanga cecropioides*, multisieriate, heterocellular, procumbent and upright cells together in body of ray, upright cells at margins. All ×72.

Fig. 3.11 (a) Fibre, (b) tracheid and (c) vessel, contrasted; intermediate cell types exist between each.

Fig. 3.12 Wood from members of the Fagaceae, TS. (a) *Quercus brandisiana*; (b) *Lithocarpus concarpa*; (c) *Nothofagus solandri*. (a) Like *Q. robur* (Fig. 3.9) has uniseriate and multisieriate rays, although only part of a multisieriate ray can be seen to the left. (b) and (c) have only uniseriate rays. (a) and (b) have tangential bands of axial parenchyma. Tyloses are present in (a), and tracheids accompany the vessels in (a) and (b). Fibres in (a) and (b) are strongly thickened. (c) Has consistently narrower vessel elements than (a) or (b), and has short radial vessel multiples. Fagaceae constitute a very natural family. There are two main anatomical groups as far as wood is concerned. (a) and (b) represent one group, (c) the other. All ×130.

Fig. 3.13 *Platymitra siamensis*, Annonaceae, TS. Vessels diffuse, porous; rays uniseriate and multisieriate; axial parenchyma in uniseriate tangential bands; fibres thick-walled. ×130.

Fig. 3.14 *Carpinus betulus*, Carpinaceae. Vessels diffuse, porous, in long radial multiples. Rays uniseriate (aggregate rays also occur, but are not shown). Axial parenchyma is seen in poorly defined, interrupted tangential bands, the cells have dark contents. ×65.
Laurus nobilis, Lauraceae. Vessels diffuse porous, narrow, solitary or in small multiples, perforation plates simple. Rays uniseriate and multisieriate, heterocellular. Fibres septate. (a) TS; (b) TLS; both ×65.

Aesculus pavia, compound sieve plate. ×720.

Diagram to show location of phloem fibres in Tilia stem TS. (b) Malvaviscus arboreus, ×218. (c) Gossypium sp., ×218. c, cambium; co, cortex; f, phloem fibres; p, functional phloem; r, ray; t, tannin; x, xylem.

Roots in TS. (a–c) Juncus acutiflorus: (a) diagram; (b) lacunate cortex, ×54; (c) root hair, ×218. (d–f) Cattleya granulosa: (d) diagram; (e) velamen, ×68; (f) ‘solid’ cortex, ×68.

Stratotis, part of root TS, SEM photograph, note air spaces in the cortex, ×75.

Root endodermis Iris sp. (a) Low-power, sector of root TS, ×20. (b) Detail from (a), ×290. c, cortex; en, endodermis; ep, epidermis; ic, inner cortex; oe, outer cortex; p, passage cell; pe, pericycle; ph, phloem; px, protoxylem.

Some root vascular systems. (a) Ranunculus acris tetrarch root. (b) Echinodorus cordifolius diarch root. (c, d) Juncus acutiflorus polyarch root. ca, Casparian strip; en, endodermis; mx, metaxylem; p, passage cell; peri, pericycle; ph, phloem; px, protoxylem. (a, b, d, e), ×300; (c), ×35.

Ranunculus (buttercup) root TS illustrating the relatively simple structure of a young dicotyledonous root. The xylem is tetrarch, and four strands of phloem alternate with the protoxylem. This root is just beginning to undergo limited secondary growth, with a cambial zone. ×100.

Iris root TS, showing a very prominent endodermis – seen here as the layer of cells with striking thickening of the radial and inner tangential walls. The endodermis is the innermost layer of the cortex. The wall thickening forces water and other molecules to take a symplasmic route from the cortex to the stelar tissue, and vice versa, through the unthickened passage cells. ×350.

Portion of a Zea mays root in this micrograph illustrates the arrangement of the separation of the cortical from the stelar tissues. Zea, like all primary roots, has an endodermis that forms the boundary between the stelar and the endodermis, and a layer immediately beneath this, the pericycle, that is the outermost layer of the stele. EN, endodermis; MX, metaxylem; Per, pericycle; PX, protoxylem; S, stele. ×500.

Stem TS of Zea mays. Maize is a monocotyledonous plant, and resembles other grasses in the arrangement of tissues in the stem leaf and root. The stems of monocotyledons generally have a single ring of vascular bundles immediately beneath the epidermis, and internal to this a system of vascular bundles that are scattered throughout the pith. ×225.

Trifolium (red clover) stem TS: a mature stem at the end of primary growth, that is, the vascular bundles contain very limited amounts of secondary xylem and secondary phloem. The cortex is very narrow and is composed of chlorenchyma. The cortex is separated from the vascular bundles and the underlying pith by a starch sheath. The pith is parenchymatous. ×125.

Hydropodermis in stem of Salvadora persica. c, cortex; h, hypodermis. ×290.

Vascular bundle types from stems. (a) Cucurbita pepo, diagram of bicollateral bundle. ×15. (b) Piper nigrum, diagram of collateral bundle; cambium remains fascicular. ×15. (c) Chondrodendrum marlatti, detailed drawing of collateral bundle, lacking cambium. ×110. (d) Juncus acutus detailed drawing of amphivasal bundle. ×220. c, cambium; scl, sclerenchyma.

Albymunious cells in gymnosperm phloem, Acmopyle pancheri, a, albuminous cell; r, ray; s, sieve cell. TS, ×290.

Diaphragm cells in leaves of Cyperaceae. (a) Becquerelia cymosa. (b) Mapania wallichii. (c) Choristandra enodii. (d) Mapanioptis effusa. (e) Sicyrophorion chaii. All ×218.

Some possible evolutionary pathways leading to variations in vascular bundle arrangements in leaves. See text for fuller commentary. (a) One row of bundles; adaxial and abaxial surfaces distinct. (b) Adaxial surface much reduced. (c) Smaller adaxial surface, leaf becoming cylindrical. (d) Loss of adaxial surface, leaf cylindrical, bundles in one ring, but ‘marginal’ bundles still distinct (m). (e) Lateral compression, leaf of this type could arise from (d) or from (f), where the adaxial surface is progressively lost. (g) Could arise from secondary dorsiventral compression of the form in (d).

Diagram of vascular bundle pair in Thunia sphaerocylindra, leaf. The small bundle is inverted so that the phloem poles (ph) of the pair are opposite one another. TS, ×57.

Hex aquifolium leaf TS and surface. (a) Low-power (×22) diagram of midrib region, A–B and C–D indicate where detailed drawings (b) and (c) were taken. (b) Detail of midrib. TS, ×130. (c) Detail of lamina. TS, ×130. (d) Abaxial surface. ×200. a, air space; ab, abaxial epidermis with thick outer wall; ad, adaxial epidermis with thick outer wall; cr, crystal; h, hypodermis; m, midrib bundle; p, phloem; pm, palisade mesophyll; s, sclerenchyma; sm, spongy mesophyll; st, stoma; tb, vascular bundle; x, xylem.

Anotral contrast, A. branddraaiensis, the granular interface between the cuticle and cell wall makes interpretation of the cuticular pattern difficult. ×400.

Cuticular patterns are more easily seen using the scanning electron microscope. (a) Low power view (×50) of Aloe raubi × A. dawei showing distribution of stomata. (b) Gasteria latzi × Aloe tenuiss var. rubra. (c) Hazorthia cymbiformis. Note that the rim to the stomatal pore is four-lobed in the hybrid plants, an Aloe characteristic. Hazorthia belongs to the group of very succulent species within the genus, and has lobes which are fused into a cylindrical collar. (b, c) ×600.

Aloe lateritia var. kataliensis wax flakes on the four lobes surrounding a stoma. The guard cells are deeply sunken and can just be seen. ×2200.

Monocotyledonous leaf surfaces. (a) Phalaris canariensis, ×240. (b) Kniphofia macowanii, ×80, note cuticular pattern. (c) Arundo donax, ×120, note microhairs. (d) Clintonia uniflora, ×70. (e) Smilax hispida, ×150. (f) Gloriosa superba, ×54, note elongated costal cells over vein and cells with sinusous walls between veins (intercostal cells). m, microhair; p, prickle hair; si, silica body.

Dicotyledonous leaf surfaces (abaxial): (a) Acaia alata; (b) Aerva lanata; (c) Plumbago zeylanicum; (d) Cassia angustifolia. All ×120.

Gasteria retata, leaf surface, showing very thick anticlinal cell walls and small lumina (l). ×145.

Diagram of ratios of height to width, note how difficult it is to judge these by eye. (b)–(h) Epidermis of selected plants in TS. (b) Gasteria retata, note the thick outer wall and the outer part of the anticlinal walls. (c) Dicentra cymororum, note that some cells are larger than
others. (d) *Elegia parviflora*, note the double epidermis. (e) *Cistus salviifolius*. (f) *Gloriosa superba*. (g) *Pinus ponderosa*, note the very thick walls. (h) *Thamnochortus scabridus*, note the wavy anticlinal walls; pits are also visible. ×45.

**Fig. 6.11** Adaxial surfaces, showing various stomatal types. (a) *Chrysanthemum leucanthemum*, anomocytic. ×109. (b) *Justicia cydonifolia*, diacytic. ×218. (c) *Plumbago zeylanicum* anisocytic. ×218. (d) *Convolvulus arvensis*, paracytic. Note elongated cells over veins. ×109. (e) *Acacia alata*, paracytic. ×218.

**Fig. 6.12** Two routes for formation of the paracytic type of stoma. In (a) → (b) → (c) guard cells are derived from the cells flanking the guard cell mother cell. In (a) → (b) → (d) the guard mother cell divides to produce two cells, each of which divides once more. g, guard cell; m, guard mother cell; s, subsidiary cell.

**Fig. 6.13** *Limonum vulgare*, TS of salt gland from leaf. c, cup cell; e, excretory cell; p, pore; t, tannin-filled cells. ×330.

**Fig. 6.14** Hairs in Centropleidaceae (a–c) and Restionaceae (d–g). (a), *Apelia cyperoides*. ×75 and ×150 respectively. (c) *Corditopsis exserta*. ×75. (d) *Thamnochortus argenteus*. ×218. (e) *Laxoarya pubescens*. ×218. (f) *Leptcarpus tenax*. Surface view, ×113; longitudinal section, ×120.

**Fig. 6.15** (a) *Mentha spicata*, range of hair types. (b) *Corylus* hair (*Corylus* also has multilocular outgrowths). (c) *Oreganum vulgare* (marjoram) hair and sunken gland. (d) *Cistus salviifolius*, range of hair types, one dendritic, the other glandular. All ×200.

**Fig. 6.16** Glandular hairs. (a) *Runcus*, brittle, sharp hair containing irritant oil droplets. ×145. (b, c) *Urtica dioica*: (b) low-power hair on multicellular base, ×20; (c) fragile, sharp tip which can be broken off easily, ×290. (d) *Salvia officinalis*, multicellular and biseriolar hairs. ×290. (e) *Justicia*. ×290. (f) *Convolvulus*. ×45.

**Fig. 6.17** Non-glandular hairs. (a) *Salvia officinalis*. ×220. (b) *Convolvulus floridus*. ×108. (c) *Coldenia procumbens*. ×220. (d) *Justicia*. ×220. (e, f) *Trigonobalanus verticillata*. ×220. (g) *Verbascum bombyciferum*. ×54. (h, i) *Artemesia vulgaris*, ×220 and ×300, respectively.

**Fig. 6.18** *Pariana bicolor*, showing bulliform and fusoid cells. (a) Low-power (<54) diagram of leaf TS, to show location of (b), detail drawing, ×218. (a) arm cells of mesophyll; b, bulliform cells; f, fusoid cell (typical of certain bamboos); scl, sclerechyma girders.

**Fig. 6.19** *Clintonia uniflora*, paradermal views (through the epidermis) of arm cells, part of the spongy mesophyll (stippled). Note large air spaces between the cells. (a) Abaxial, ×115; (b) adaxial, ×80.

**Fig. 6.20** Strengthening tissue in the leaf, as seen in TS. Sclerenchyma in *Agave franzoni* (a, b), *Aegilops crassa* (c, d), *Phalaris canariensis* (e). (a) Outline of leaf TS to show location of diagram (b, ×40). (c) Leaf margin. ×109. (d, e) Vascular bundles and their associated bundle sheaths and girders. ×109; (e) ×210. adg, adaxial sclerenchyma girders; abg, abaxial sclerechyma girders; c, chlorenchyma; is, inner bundle sheath; ms, marginal sclerenchyma; mx, metaxylem; os, outer bundle sheath; p, prickle hair; ph, phloem; vb, vascular bundle; x, xylem.

**Fig. 6.21** *Pinus ponderosa*, plicate mesophyll cells from TS. ×145.

**Fig. 6.22** Selected sclereids from leaves. (a) *Olivacea radiata*. (b, c) *Olea europaea*. (d) *Camellia japonica*. All ×290.

**Fig. 6.23** Crystals, cystalloth and tannin and latex cells. (a) Styloloid crystal, typical of many Liliaceae. (b) *Acacia alta*, crystals from leaf. (c) Cluster crystals in *Passiflora foetida* leaf. (d) *Ficus elastica*, leaf TS showing cystalloth; dark cells contain latex. (e) *Oscularia deltoidea*, leaf TS with large tanniniferous idioblasts (t) and raphides. ×125.

**Fig. 6.24** Various silica bodies. (a) *Cymophyllus fraseri* (Cyperaceae) leaf TS. Note location of silica bodies (si) in epidermal cells above sclerechyma girders. ×218. (b) *Aegilops crassa* (Poaceae) abaxial leaf surface. p, prickle hair; si, silica body; st, stoma. ×109 (c–d) Isolated silica bodies. (e) *Zea mays* (Poaceae) ×200. (d) *Bambusa vulgaris* (Poaceae) ×200. (e) *Agrostis stolonifera* (Poaceae) ×200. (f) *Eryngium montana* (Cyp.). ×200. (g) *Cyperus diffusus* (Cyp.). ×200, first body in surface view, second in side view. (h) Typical of many palms and Restionaceae. ×300.

**Fig. 6.25** SEM photograph of a fragment of chaff from one of the Gramineae, found in fragments of a bell mould from ruins at Cheddar. Note the outline of silica bodies. ×1000.

**Fig. 6.26** Aspects of Hickey’s classification system. Many species have first order lateral veins that emerge from the midrib vein, which then arc outwards and upwards towards the lamina margin, without terminating at the leaf margin. This is defined as eucamptodromous. In (b) the first order lateral veins are outwards and upwards from the midrib, and terminate at the leaf margin, where their endings often form teeth. This is defined as simple craspedodromous. In (c) the first order lateral veins overarch beneath the leaf margin, forming a primary interconnected network. This is defined as brochiodromous. In (d) the leaf contains three similar-sized veins, which effectively form three compartments in the leaf. This is an example of an actinodromous leaf. In (e) the first order lateral veins overarch, and extensions continue to the leaf margin, which is serrated in the semicraspedodromous leaf. The first order lateral veins branch several times near the margin of the lamina in the cladodromous leaf illustrated in (f). In reticulodromous leaves, the first order lateral veins branch many times towards the margin of the lamina. In parallelodromous leaves the three orders of lamina vein make up a longitudinal system of parallel veins. In palinactodromous leaves (e) the leaf is dissected at its base into a number of arms. In (d) and (e) each of the basally attached veins is the same size. (Redrawn from Hickey, 1973.)

**Fig. 6.27** *Plumbago zeylanicum*, paradermal view of veins to show open type of venation. Note enlarged tracheids (t) at veinlet ends. ×20.

**Fig. 6.28** Micrographs showing the size change relationships between the companion cell and the sieve tube cell in loading, transport and unloading phloem. *Nymphoides*: (a) Minor vein in leaf lamina. (b) Phloem in central vascular bundle in the submerged petiole. (c) Phloem strand from a root. Scale bars: (a) 20 μm; (b, c) 10 μm. CC, companion cell; S, sieve tube member; T, tracheary element. (a) ×250; (b, c) ×500.

**Fig. 6.29** Bundle sheaths. (a) *Briza maxima*, inner mestome (sclerechyma) sheath, outer parenchyma sheath, abaxial and adaxial sclerechyma strands and radiate chlorenchyma. ×120. (b) *Gloriosa superba*, parenchyma sheath only. ×120. (c) *Cymophyllus fraseri*, parenchyma, followed by mestome sheath and outer parenchyma sheath. ×128. (d) *Fimbristylis*, three sheaths, inner parenchyma, followed by mestome sheath and outer parenchyma sheath. ×218.

**Fig. 6.30** (a, b) Line drawings based on electron micrographs of typical Panicoid and Pooid leaf blade bundle anatomy. BS, parenchymatous bundle sheath; IS, intercellular space; MS, mestome sheath; PS, parenchymatous (Kranz) sheath; VP, vascular parenchyma cell. ×1000.

**Fig. 6.31** Electron micrograph, showing a small transverse vein of *Saccharum officinarum* in transverse view. This vein is surrounded by two sheaths; an outer bundle sheath (BS) and an inner mestome sheath (MS). Bundle sheath mestome sheath interfaces are often associated with a suber lamina. The vascular tissue consists of metaxylen vessel and associated parenchyma, whilst the phloem contains several sieve tubes and associated parenchyma and companion cells. ×1650.

**Fig. 6.32** Line drawings (a–c) showing the basic anatomical features of leaf blade bundle structure in the Cyperaceae. The variation of cell thickness is most notable in the cell walls of the endodermis. Note the distribution of chloroplasts in the border parenchyma and the
presence of large chloroplasts (agranal in some species) in the border parenchyma. Examples are, left: *C. fastigiatus*; *C. esculentus*; *Maricurus congestus*; centre: *C. saxangularis*; *C. pulcher*; *C. accutiformis*; right: *C. alboatriatus*; *C. textilis*; *C. papyrus*. E., endodermis; IS, intercellular space; PS, parenchyma sheath. ×850.

**Fig. 7.1** Floral vasculature of (a) *Gaylussacia frondosa* (Ericaceae) with common bundles and (b) *Nestoria umbellulata* with inverted bundles that give rise to the carpel bundles. DC, dorsal carpel bundles; IB, inverted bundles.

**Fig. 7.2** Surface details of two pollen grains for comparison. A, *Crocos micchelioni*, B, *Crocos walliscola*, both SEM photographs, ×1,000.

**Fig. 7.3** *Tradescantia pallida*, pollen grain germinating on stigmas. p, pollen grain; pt, pollen tube; s, papilla on stigma. Freeze dried, viewed in SEM, ×1,000.

**Fig. 7.4** Fruit wall and seed coat details in TS. (a) *Aesculus hippocastanum*, outer part of fruit wall. ×109. (b) *Fagus sylvatica*, outer part of fruit wall. ×109. (c) Outer part of seed coat of *Delphinium staphiagria*. ×109, note small outgrowths from epidermal cell walls. (d) *Cicer aritinum*, seed coat. ×218. (e) *Cola acuminata*, seed coat. ×218. (f) *Cucurbita pepo*. ×109. c, cells with U-shaped wall thickening; e, epidermis; ep, epicarp; h, hour glass cell; ie, inner epidermis; m, mesocarp; oe, outer epidermis; p, parenchyma; pa, palisade cells; pc, pitted cells; r, reticulate spongy parenchyma; s, sclerenchyma; sl, sclerenchyma layer.

**Fig. 7.5** Transverse sections of the exocarp of the fruits of *Antbusium* showing anatomical variation: (a) *A. perigina*; (b) *A. arzenis*. MS, macrosclerid; SC, slime cell; Scler, sclerenchyma; TI, tracheoidal idioblast. (After J. Briquet 1916.)

**Fig. 7.6** Epidermal slime trichomes on the exocarp of *Matricaria lamellata*. (a) Surface view of a slime trichome cluster. (b) Transverse section of a slime trichome cluster. (c) Longitudinal section of a slime trichome cluster. (After Alexandrov & Savcenko 1947.)

**Fig. 7.7** Transverse sections of the epidermis of two species in the Mint Family. Note the tall pallisade like sclereids. (a) *Coleus barbatus*. (b) *Lavandula spica*. EN, endocarp; IE, inner epidermis. (After S. Wagner 1914.)

**Fig. 7.8** Diagrammatic representations of the development of the stony endocarp in fruits from the inner epidermis (IE) and inner hypodermis (IH). (a) From the epidermis only. (b) From the hypodermis only. (c) From the epidermis and the multiple hypodermis. (d) From a single hypodermis only. (e) From a multiple hypodermis only. (f) From both a multiple epidermis and a multiple hypodermis. Stippling indicates stony layer.

**Fig. 7.9** Examples of ruminate endosperm in (a) *Asimina triloba* and (b) *Hedra helix.*

**Fig. 7.10** Anatomy of the winged seeds of two genera in the Lecythidaceae in transverse section. (a–d) *Asimina triloba*. (a) Whole seed. (b) Abaxial leaf surface. Both SEM, ×109. (c) Longitudinal section of a slime trichome cluster. (After Alexandrov & Savcenko 1947.)

**Fig. 8.1** (a) *Aloe somaliensis*, outer part of leaf TS. ×218. (b) *Haworthia greenii*, outer part of leaf TS. ×218. Note the sunken guard cells (g), the thick cuticle (c) and the thick outer wall to the epidermal cells (e). Both have succulent leaves, with little mechanical tissue.

**Fig. 8.2** *Amophila arenaria*. (a) Low power, plan leaf TS. (b) Detail of rib (black areas represent thick walled cells). (c) Adaxial epidermis with stomata. ×300. (d) Abaxial epidermis with very thick cuticle. ×300. s, sclerenchyma; V, vascular bundles; h, hairs; st, stoma.

**Fig. 8.3** (a,b) *Crassula sp.* (c–e) *Senecio scopasus*. (a,c) Plan TS leaf; mechanical tissue absent, central mesophyll cells store water. (b) Detail of outer part of (a). (d) Outer part of (c). (e) Central part of (c, b,d,e) ×54. c, chlorenchyma; h, hair; t, tannin; v, vascular bundle; w, water storage tissue.

**Fig. 8.4** (a,b) *Hakea scoparia*, leaf TS. (c,d) *Leptocarpus tenas*, stem TS. Note sunken stomata (st) in both and abundant strengthening sclerechyma (s). Hairs (b) show the *Leptocarpus* and tannin (t) is present in the chlorenchyma of *Hakea*. The pillar cells (p) in *Leptocarpus* divide the chlorenchyma into longitudinal channels. c, chlorenchyma; v, vascular bundle. (a,c) ×15; (b,d) ×120.

**Fig. 8.5** *Echeveria*, outer part of stem. Fibres and sclereids show as lighter cells. This xerophyte has a deeply grooved stem, with stomata on the flanks of the grooves. Note the strong development of hypodermal fibres to the outer side of the thin-walled chlorenchyma. TS in polarized light, ×550.

**Fig. 8.6** Small parts of mesophyte leaves (lamina) in TS. (a) *Arbutus unedo*. ×109. (b) *Corylus avellana*. ×120 (c) *Olea europaea*. ×109. c, cluster crystal; h, hair; p, palisade; sc, sclereid; sp, spongy mesophyll; st, stoma; v, vascular bundle.

**Fig. 8.7** *Codanathe sp.* Part of leaf TS showing multiple epidermis (m), a single palisade (p) and a large quantity of spongy mesophyll (s). ×102.

**Fig. 8.8** *Limnophyton obtusifolium*, part of midrib, TS. (a) Diagram showing large air spaces around central vascular complex. ×15 (b) Laticifer. ×110. (c) Central vascular tissue. ×200. a, air space; l, laticifer; lp, loose palisade chlorenchyma; p, phloem; t, tracheary element.

**Fig. 9.1** Some differences between Restionaceae, Ecdieiocoleaceae and Anarthriaceae. (a,b) Restionaceae. Stem TS, most species have the general anatomy shown as (b), with a continuous parenchymatous sheath; in some genera the sheath is interrupted by extensions from the sclerenchyma cylinder, as in (b). No vascular bundles occur in the chlorenchyma in all but one or two species. None of the species has hypodermal fibres or lacks a sclerenchyma cylinder as exhibited by Ecdieiocoleaceae (d). Anarthriaceae (c) differ in addition by having subepidermal fibre strands associated with vascular bundles; they may also have a sclerenchyma cylinder. Neither Anarthriaceae nor Ecdieiocoleaceae have a parenchyma cylinder. c, chlorenchyma; e, epidermis; p, parenchyma cylinder (interrupted in (b)); s, sclerenchyma.

**Fig. 9.2** Group of stomata in abaxial surface of *Eleutharbee macrocarpa*. (A) In (b), *Pychnarbee pennisifera*, the stomata are scattered over the abaxial leaf surface. Both SEM, ×300.

**Fig. 9.3** Shoot of potato from meat pie, mistaken for something worse!

**Fig. 9.4** Starch grains: (a) potato; (b) maize; (c) oat; (d) rice; (e) pea; (f) banana; (g) wheat. (h) Starch grains in xylem ray tissue of *Fabrisinapis*, SEM. (a–g) ×200, (h) ×3000.

**Fig. 9.5** *Acer pseudoplatanus* roots grown under different conditions (TS). (a) From normal and (b) from waterlogged soils. (c) Normal trunk wood. All ×130.

**Fig. 9.6** Charcoal of *Alinus glutinosa* from Romano-British London. Details of the structure are well preserved, particularly the scalariform
perforation plate.

Fig. 9.7 An Egyptian sandal from antiquity, found to be made from papyrus (*Cyperus papyrus*) and palm species of *Borassus*.

Fig. 10.1 A simple apparatus for producing a steam jet to soften wood prior to sectioning.

Fig. 10.2 Preparing a cork for holding material to be sectioned A–D for TS, E–H for LS; note that the oblique cut in cork E helps to prevent cylindrical stems from being released from the cork on clamping.

Fig. 10.3 The wrong way to cut cork for making LS of material. When clamped, the cork curls back and the specimen is released.

Fig. 10.4 Long leaves can be folded several times before sectioning. Several sections will then be obtained with each cut.

Fig. 10.5 Drawing a curled section onto a microscope slide.

Fig. 10.6 Preparing leaf surface for microscopy by the scraping method.

Fig. 10.7 Selection of standard levels for comparative work. For wood, a cube is prepared so that it will provide working transverse, tangential longitudinal and radial longitudinal faces.

Fig. A2.1 A screen dump showing the contents page of *The Virtual Plant*. Note the Presentation Files, Digital Plant Anatomy and The FactFiles links.

Fig. A2.2 Starch grains, iodine-potassium iodide negative image.

Fig. A2.3 A typical *Virtual Plant* roadmap, from which elements of the exercise may be selected in any order. It illustrates the specimens which have been included in this exercise. Clicking on these will short cut the reader to the specimen concerned. So, if you want to look at the *Trifolium* stem, simply double click on the image. All images are shown as 24-bit colour thumbnails for web viewing.

Fig. A2.4 Screenshot of the *Nymphaea* exercise.

Fig. A2.5 Screenshot of the *Nymphaea* exercise, detailing the anatomy of the waterlily.

Fig. A2.6 Screenshot of the *Nymphaea* exercise.

Fig. A2.7 Illustration of secondary wood structure in this *Virtual Plant* exercise.

Fig. A2.8 Detail page with information relating to a cross-section of the wood of the conifer *Fitzroya cupressoides*.

Fig. A2.9 Vanishing-point reconstruction in 3D.

Fig. A2.10 Screenshot of the *Oldenburgia* exercise.

Fig. A2.11 Screenshot of a *Nymphaea* vascular bundle, from plant adaptiveness.

Fig. A2.12 Screenshot of leaf anatomy from the plant adaptiveness exercise.

Fig. A2.13 Screenshot of *Crassula* from the plant adaptiveness exercise.

Fig. A2.14 Typical screenshot from the Glossary – the glossary definition for an endodermis.

Fig. A2.15 Screenshot of the digital plant anatomy pages.

Fig. A2.16 Screenshot of the digital plant anatomy pages, showing 12 thumbnails of leaf images.

Fig. A2.17 Screen shot of index to PowerPoint Presentations.

Fig. A2.18 Screenshot of the Factfile Index.