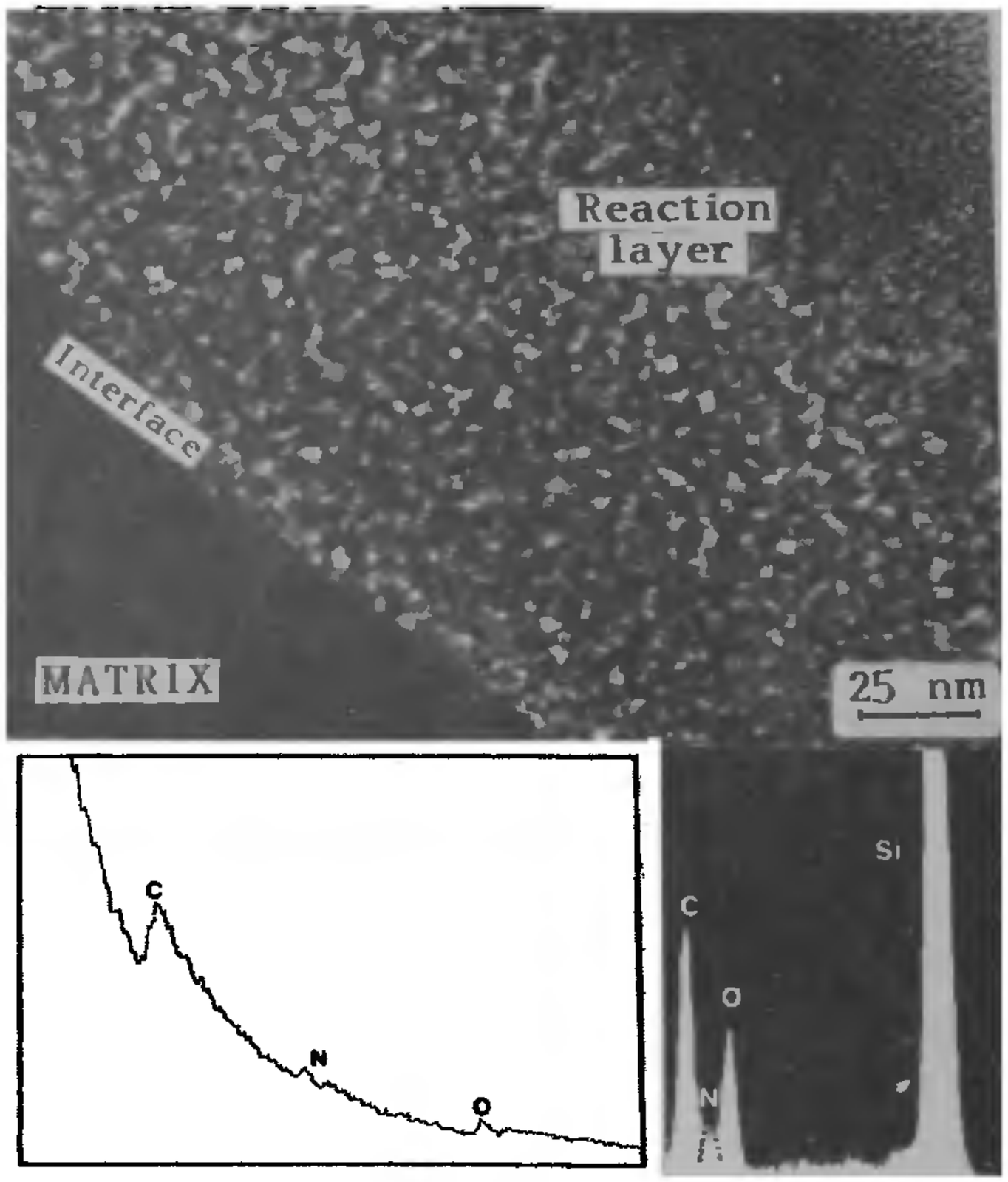

Figure 2. Interface reaction layer in a MAS/HPZ nitride-based fibre composite with accompanying EELS and EDAX analysis.

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Structure of sola wood: the traditional Indian art material

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Sola wood, produced by the Indian aquatic shrubs *Aeschynomene aspera* and *A. indica*, is the lightest wood known. It is a marble-white, soft, and spongy material used by traditional Indian craftsmen to produce a wide range of decorative articles. In commerce this wood is erroneously called sola pith. Sola results from the activity of vascular cambium and has all the components of wood (secondary xylem). The present work provides the structural basis of the varied uses of this versatile natural material. Wood structure is similar in both the species except for the presence of growth rings in *A. aspera*. The wood is storied and diffuse porous. The frequency of vessels is extremely low. Inter-vessel pits are bordered and vestured. A few vessels have vestures or helical thickenings on the inner surface of their walls. Axial parenchyma is paratracheal vasicentric or scanty vasi-

centric. Rays are usually uniseriate and rarely biseriate. Occasionally multiseriate rays with radial vessels are present. In cross-section fibres appear as aliform patches around certain vessels. The wood chiefly consists of thin-walled fusiform cells, endowed with abundant simple pits on end walls, giving them a sieve-like appearance. Pits are rare or absent on tangential walls. The term 'fusiform wood cells' has been coined by us to demarcate them from other wood components. It is inferred that fusiform wood cells are involved in short-distance transport of water but eventually become filled with air to provide the wood its characteristic properties.

THE extremely light wood (specific gravity 0.04)[1] of *Aeschynomene aspera* Linn. and *A. Indica* Linn. is used for preparing artistic and delicate decorations for Hindu idols of Durga, Saraswati, Ganesha, etc. during festivals in India, crowns (*mukut* or *topa*) for Hindu brides and bridegrooms in certain parts of India, 'shera' the bridal veil of Muslims, tazias in the Muslim festival of Muharram, garlands, floats for fishing nets, life belts, insulating material, cushions, hats (*sola topi*), multi-coloured toys, artificial flowers, ornaments, lining of palanquin-tops and fish-baskets[2-8]. Exquisite models of temples, ships and a variety of other objects of art are produced from this wood in Tamil Nadu, West Bengal and Orissa. High quality sola comes from West Bengal[4].

Solereder[9] reported that the ground-mass of wood in *Aeschynomene elaphroxylon* (Syn. *Herminiera elaphroxylon*) consists of radial rows of wide thin-walled hexagonal cells having sieve-like end walls with numerous pores. He also recorded that there are no annual rings in the wood of seven species of *Aeschynomene*. Metcalfe and Chalk[10] and Butterfield[11] noted that parenchyma constitutes the major part of the secondary xylem in *Aeschynomene*. Cumbie[12] suggested that the ground-mass of secondary xylem in *A. virginica* is made up of extremely thin-walled parenchyma-like cells which do not show any change in length from pith outwards. Prakash[13] considered these cells as fibres based on anatomical study of *A. sensitiva*. These reports neither give a clear picture of the nature of the ground-mass in the secondary xylem of *Aeschynomene* nor relate it to the unusual properties of the wood. The present work was taken up to provide the structural basis of the properties of the wood as a unique material.

A. aspera is a shrub that grows up to 3.6 m in swamps, river banks, tanks or lakes. In India it is generally distributed in Assam, West Bengal, Bihar, Orissa and Peninsular India[8]. *A. indica* is found throughout India, including the Andaman group of islands in the paddy fields. These plants bear stem nodules in addition to root nodules induced by *Rhizobium* spp. for nitrogen fixation. The wood of *A. aspera* is commercially more important than that of *A. indica* as it is softer and can be more easily peeled[4]. The harvested stems (5 cm diameter) are cut into 60–90 cm long pieces and stored until dry. The bark is then removed and the wood peeled into thin sheets of required sizes[4,8].

Portions of mature stem of *Aeschynomene aspera* and *A. indica* were fixed in FAA (formalin : acetic acid : ethanol; 1:1:9) and air was evacuated from the tissues to ensure penetration of the fixative. They were processed for microtomy using standard methods[14]. Sections of 10–15 μm thickness were cut and stained in toluidine blue O[15]. Material was prepared for scanning electron microscopy as described earlier[16].

Growth rings are distinct in *A. aspera* (Figures 1, 2) and are absent in *A. indica* (Figure 3). The latewood cells are thick-walled and tangentially flattened, whereas earlywood cells are thin-walled and radially wide in *A. aspera* (Figure 2).

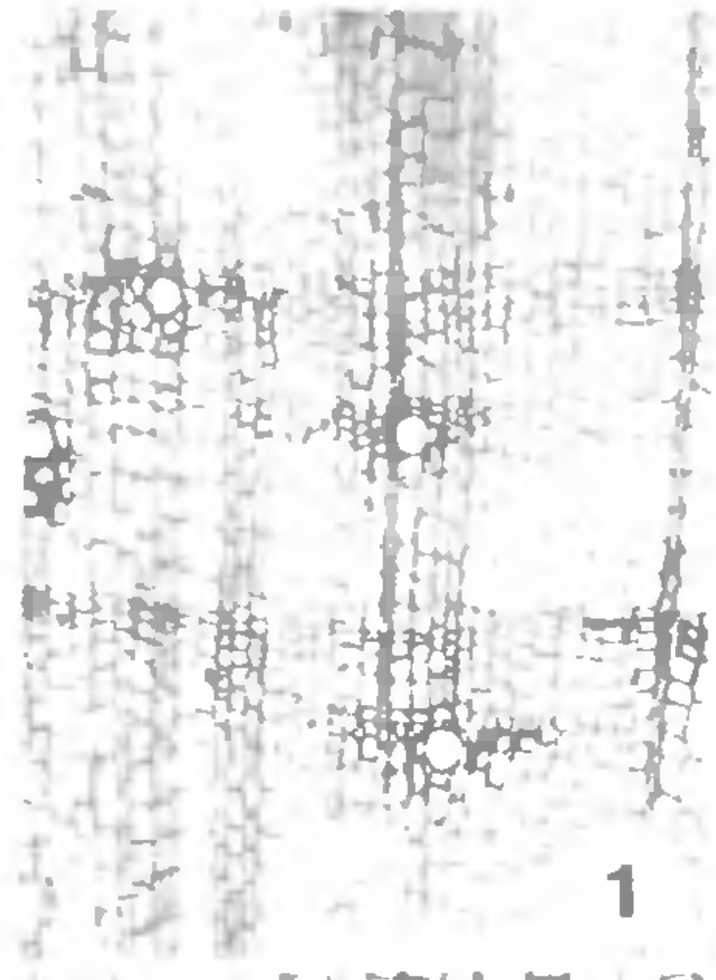
The wood is diffuse porous in both the species. Vessels are predominantly solitary (Figures 1, 3) but occasionally occur in small radial multiples (Figure 1) or in clusters or rarely in tangential rows (Figure 4). The vessel dimensions are given in Table 1. The perforation plate is simple. Inter-vessel pits are bordered, vestured and alternate (Figure 5). The vestured pits belong to type 2(iii) according to the classification of Nair and Mohan Ram[17]. At times pit borders are highly reduced or absent (Figure 6). Occasionally transitional pitting is observed in which some pits extend along the full width of the vessel face, whereas at other points two or more pits are present (Figure 7). Some vessel element walls have helical thickenings or vestures on the inner wall surface (Figures 8, 9).

Axial parenchyma is paratracheal vasicentric or scanty vasicentric (Figure 10). It may, also, appear as lateral extension from the vessels. Parenchyma cells are living and contain nuclei (see arrows in Figures 10, 11). Each parenchyma strand has two or more cells. However, fusiform parenchyma cells are also observed. Occasionally axial parenchyma cells become divided into chambers, either vertically or transversely, with each chamber containing a large single crystal (Figure 12).

Rays are homocellular and contain only procumbent cells which are radially elongated (Figure 13). They are predominantly uniseriate (Figure 14) and rarely biseriate or multiseriate. The multiseriate rays are broad and contain vascular strands in which vessels have simple perforation plates and bordered pits with reduced

Table 1. Characteristics of the vessels of two species of *Aeschynomene* (mean of 50 readings)

Features	*A. aspera*	SD	*A. indica*	SD
Mean vessel element length (μm)	145.26	45.3	130.70	34.10
Mean vessel element diameter (μm)	44.80	9.60	57.30	17.60
Frequency of vessel/mm^2	2.70	0.90	2.00	0.65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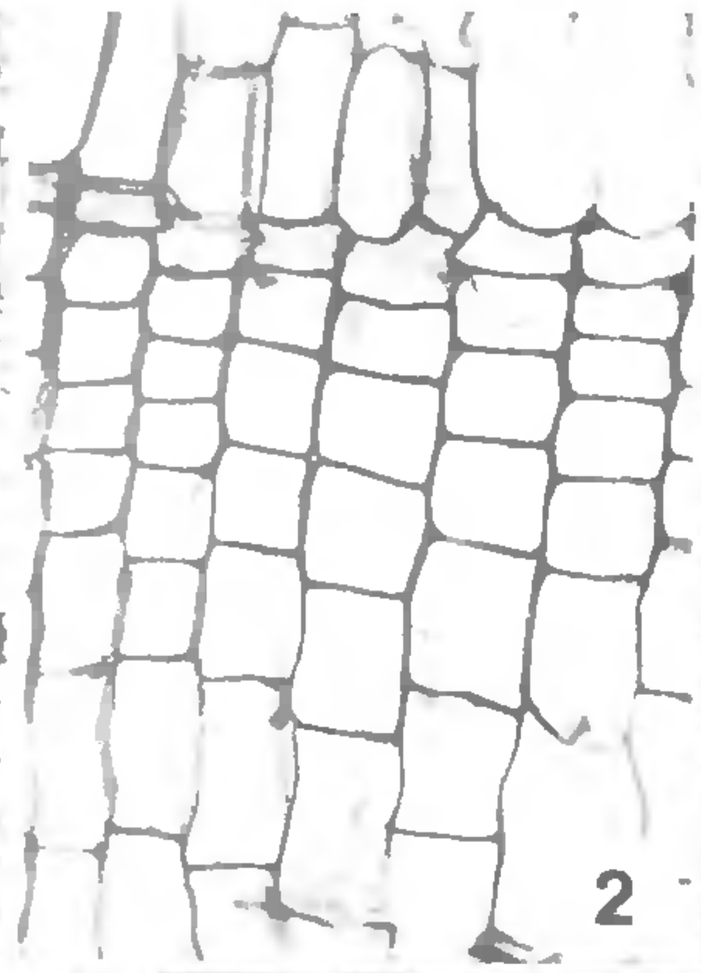
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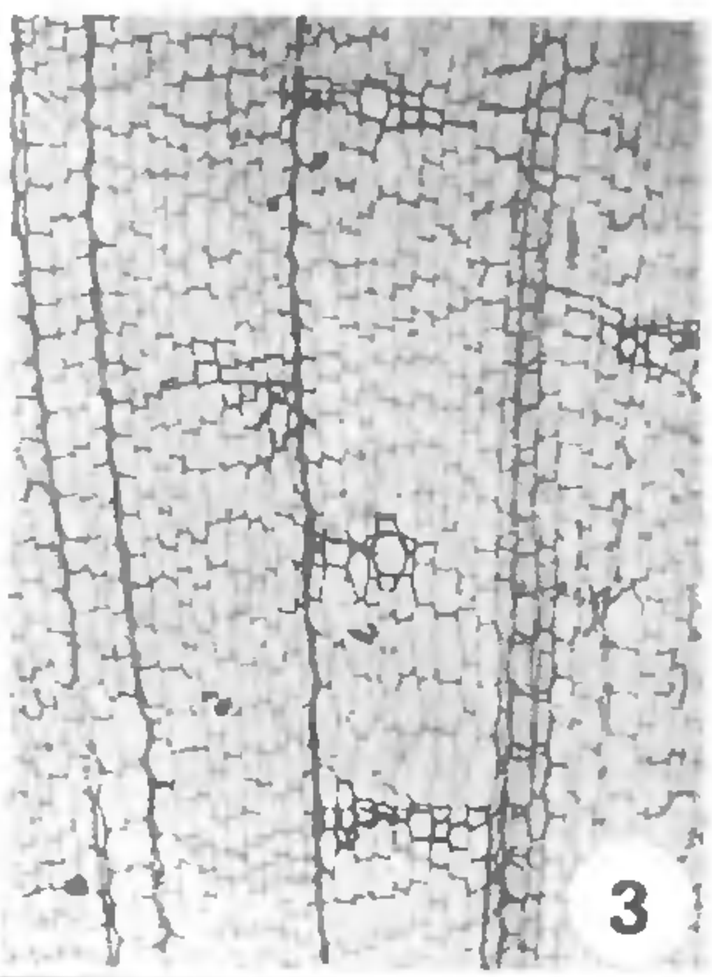
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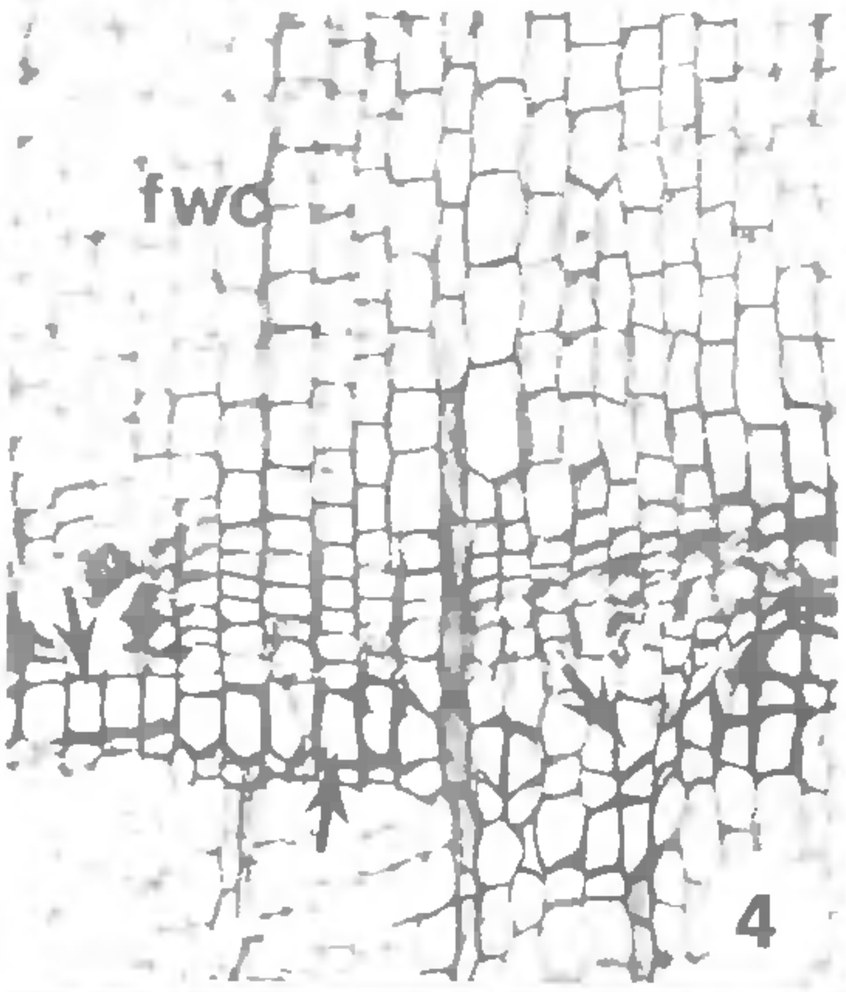

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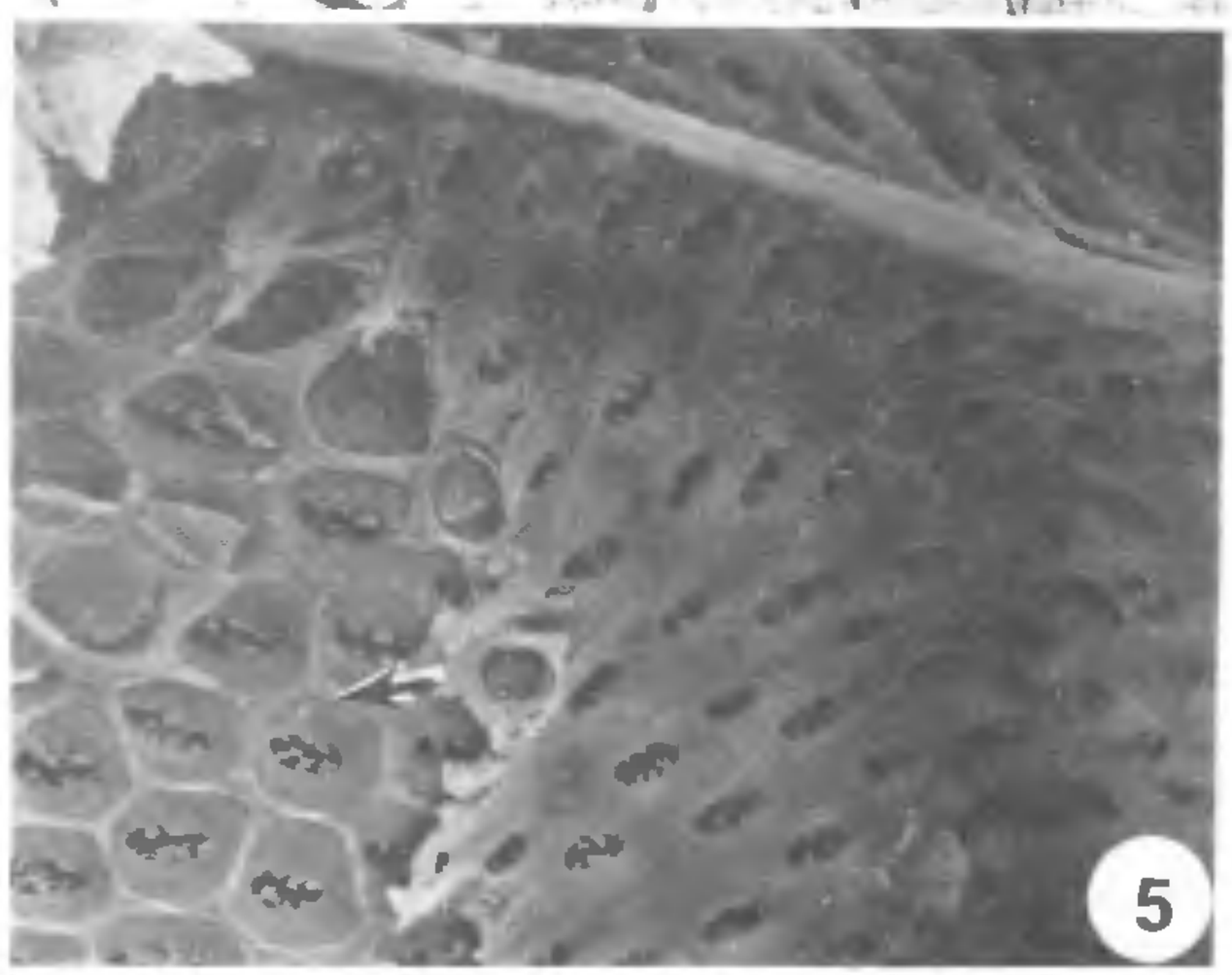
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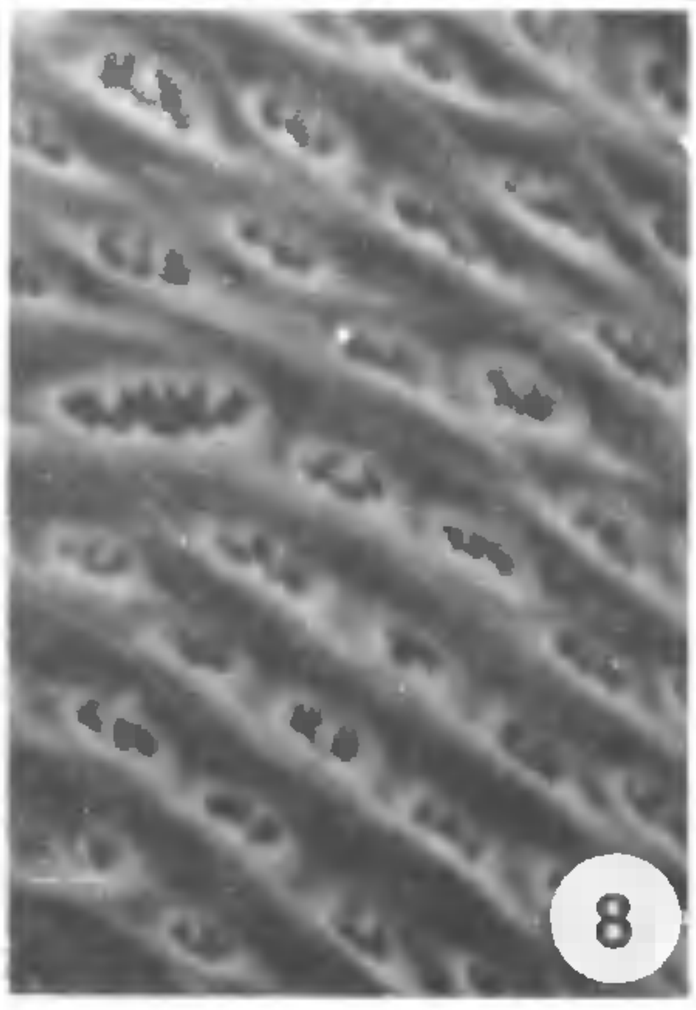
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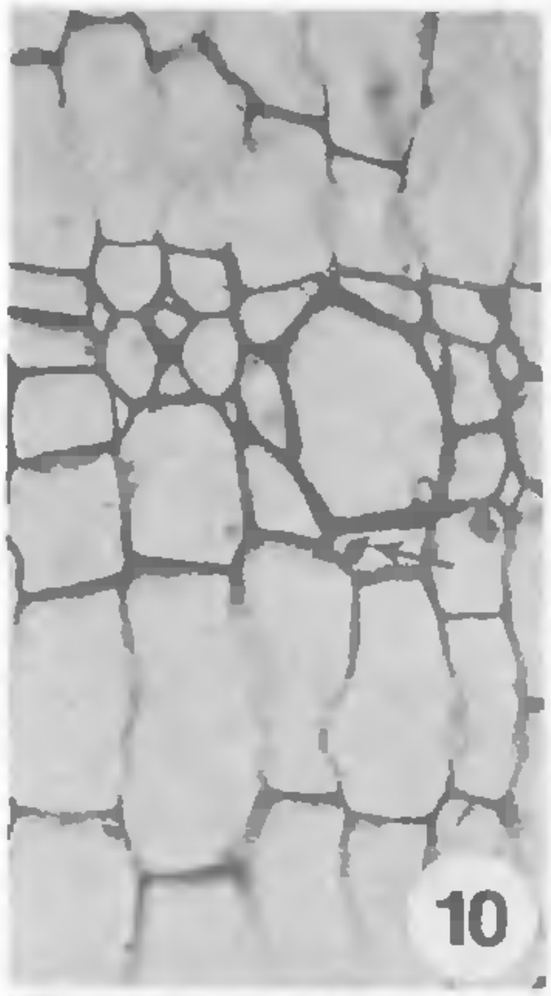

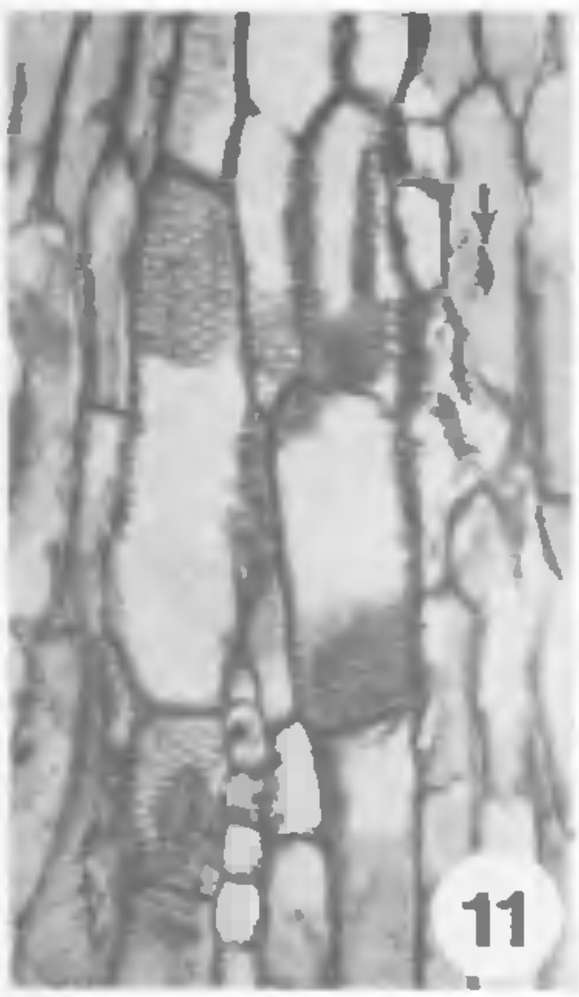

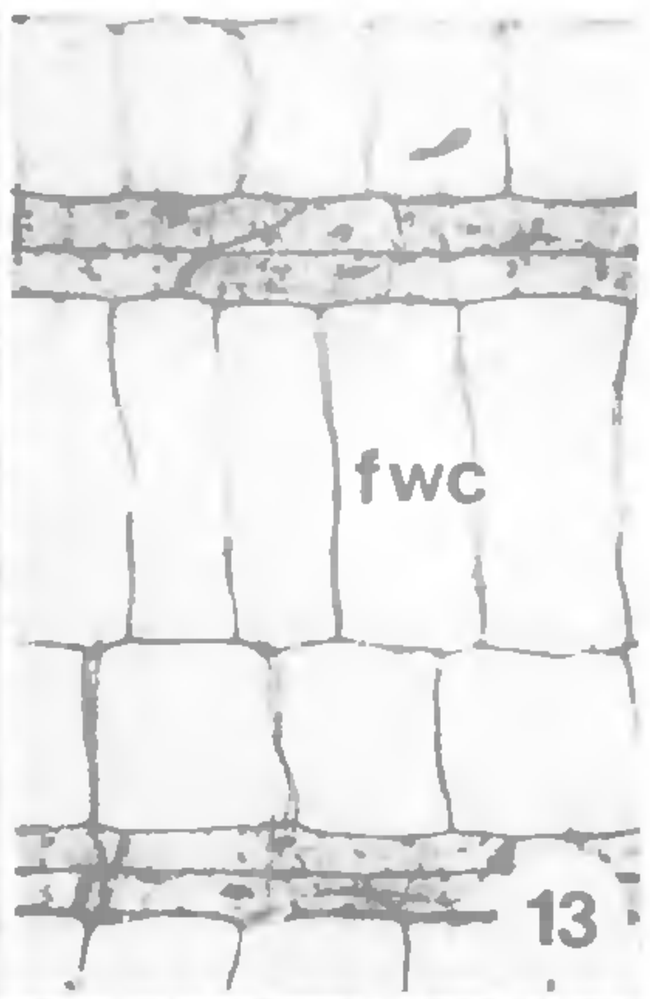

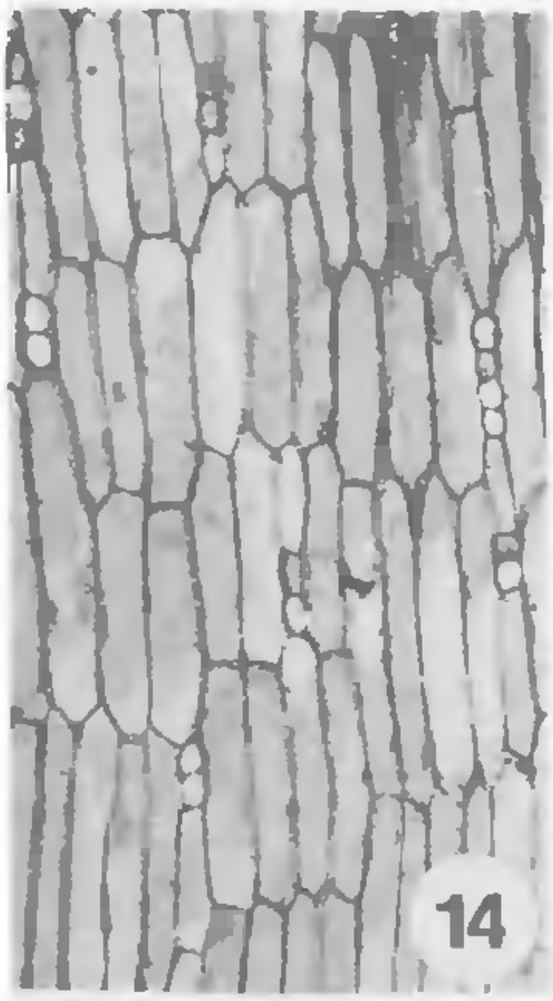

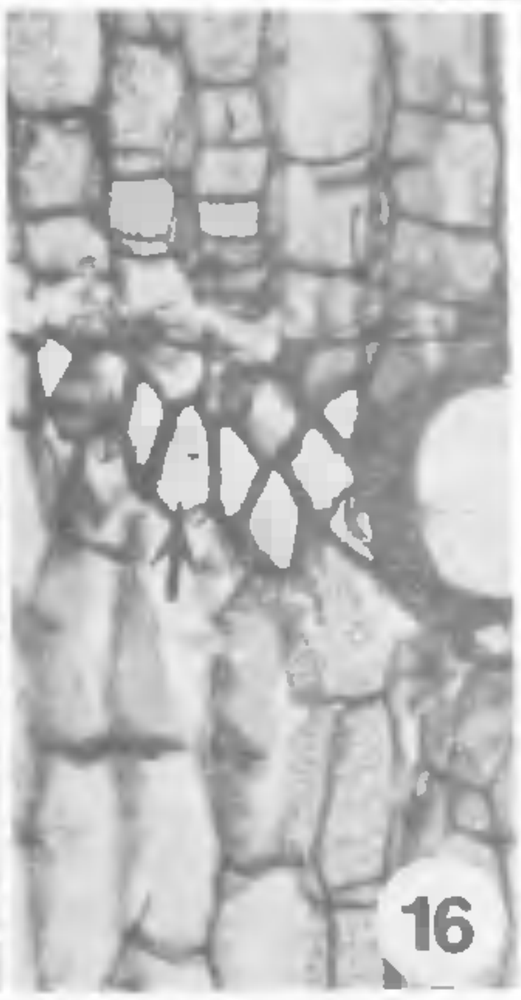

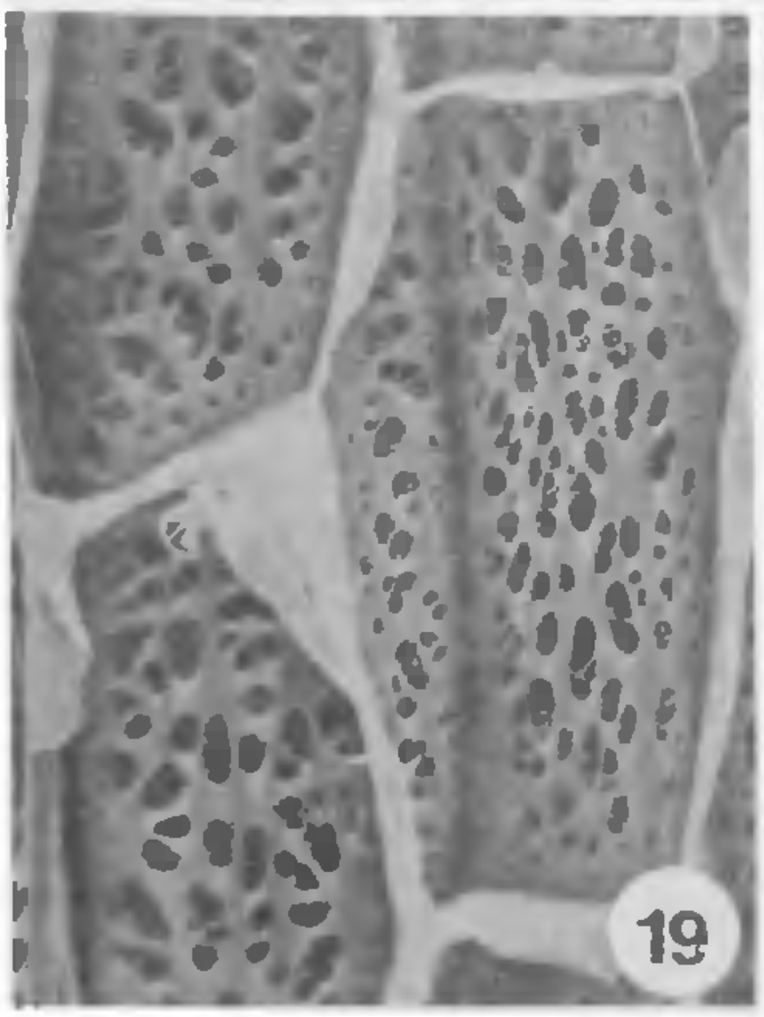

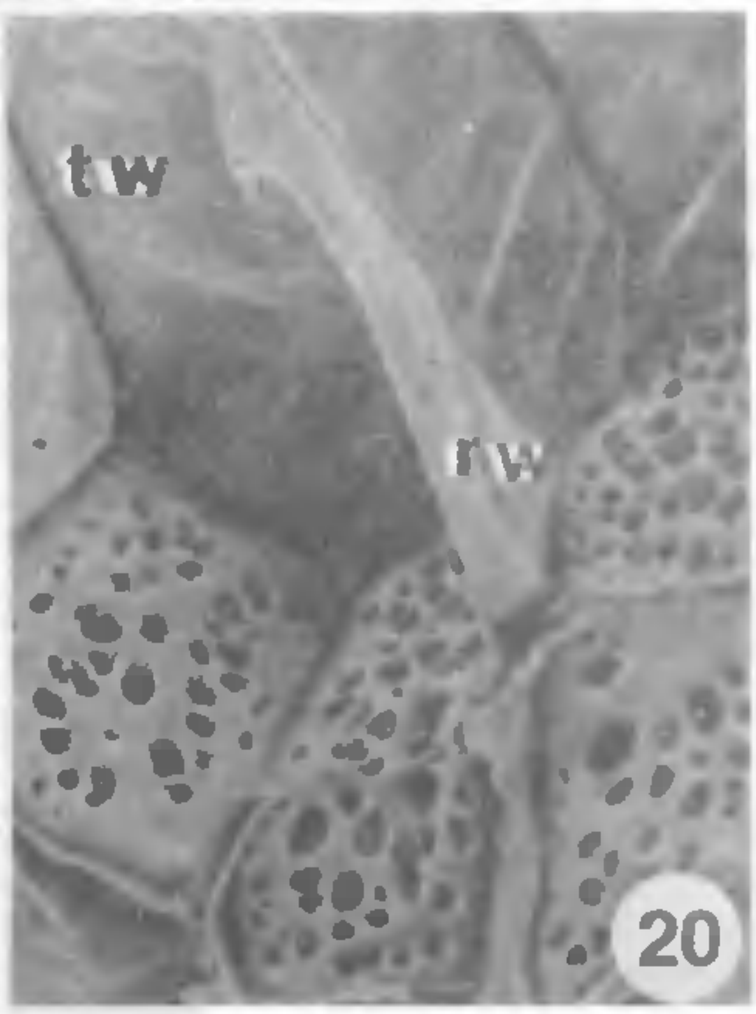

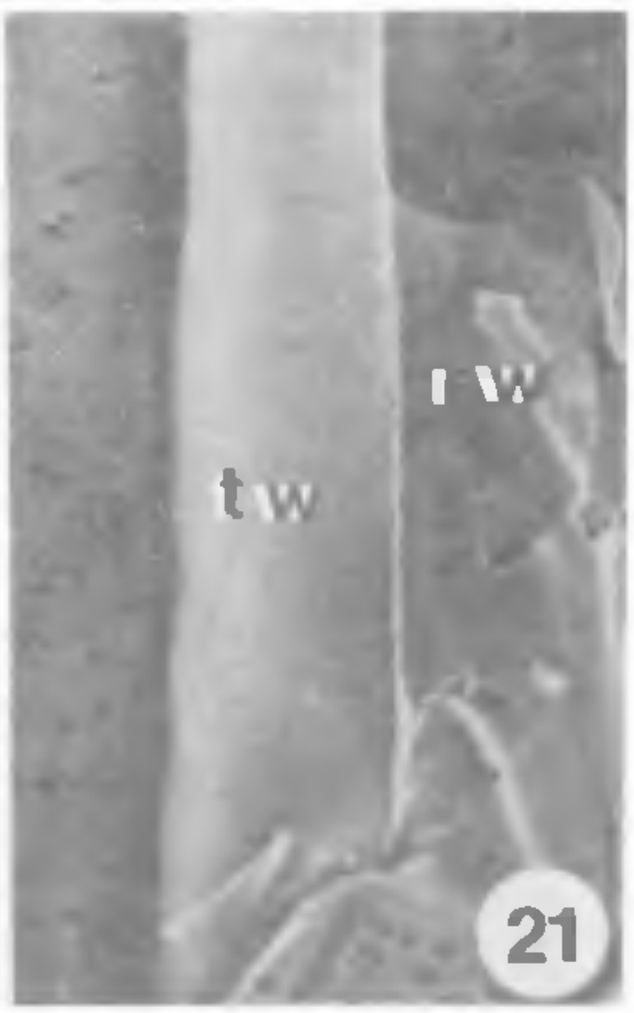

Figures 10–21. For captions, see page 750

borders and large pit apertures (Figure 15). The pits may be opposite or alternate and are sometimes of transitional types.

Fibres occur as aliform patches around certain vessels (arrow in Figure 16). They have pointed tips and thick lignified walls. Fibres show a little intrusive growth and are storied (Figure 17). They are dead cells and are devoid of protoplasmic contents at maturity.

The bulk of secondary xylem in *A. aspera* and *A. indica* consists of thin-walled cells (Figures 1, 3) which reflect the storied nature of the cambium (Figure 14). They do not undergo elongation during differentiation, a feature also noticed by other investigators[11,12]. They have larger radial diameter than the tangential ones except in the latewood of *A. aspera* (Figures 1–4). They are fusiform in tangential view (Figure 14) and their end walls have numerous large simple pits (Figures 18–20, 22). Surprisingly, the tangential longitudinal walls have only a few or no pits (Figures 20–22). The radial walls have pits which are fewer and smaller than those on the end walls (Figures 20–22). At maturity these cells are devoid of nuclei and cytoplasmic contents: they become filled with air. We have coined the term 'fusiform wood cells' for these wood components.

The present work has clearly shown that commercial sola, the wood of *A. aspera* and *A. indica* consists of vessels, fibres, axial parenchyma, rays and fusiform wood cells. Many earlier workers reported that the bulk of the secondary xylem in *Aeschynomene* is made up of parenchyma[9–12]. However, Prakash[13] believed that the ground-mass of secondary xylem in *A. sensitiva* consists of fibres and not parenchyma. The present study has shown that the secondary xylem in *A. aspera* and *A. indica* is mainly composed of neither fibres nor conventional parenchyma cells but of fusiform wood cells. The presence of abundant large pits (rather than pores, reported by Solereder[9]) on the end walls of fusiform wood cells prompts us to presume that they assist in short distance ascent of water. The low frequency of vessels also indicates the necessity of an alternate transport system. The radial transport system

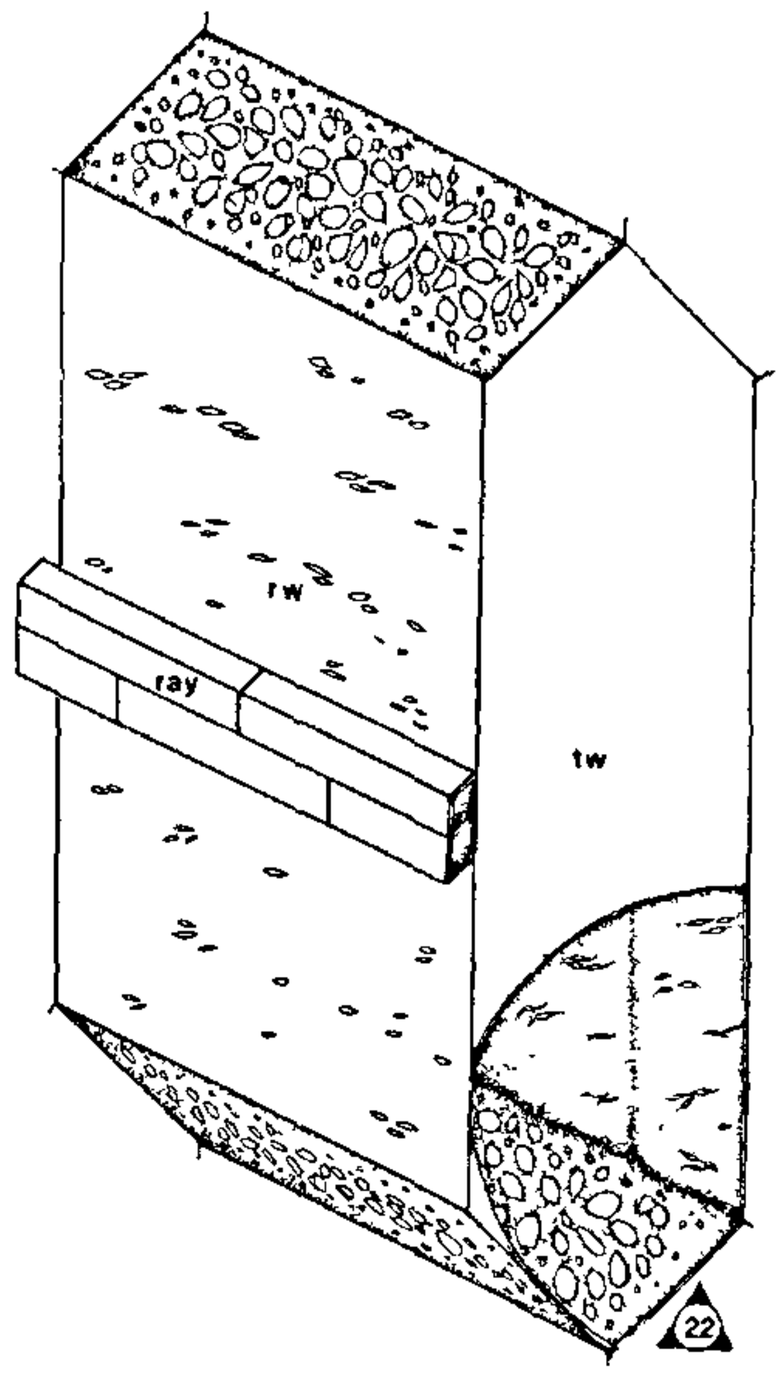

Figure 22. Diagrammatic representation of a fusiform wood cell. f, Fibre; fwc, fusiform wood cell; rw, radial wall; tw, tangential wall.

must be exclusively through rays, as the fusiform wood cells do not have pits on their tangential walls. As the stem reaches maturity the fusiform wood cells become filled with air and assist the plant in maintaining buoyancy in water as the plant lacks air-cavities.

Sola wood shows a marked reduction in the number of vessels and fibres. The restricted distribution of fibres around certain vessels indicates that besides providing support they also help in preventing the vessel walls from collapsing. The large-scale replacement of fibres

Figures 1–9. **1**, Portion of cross-section of wood of *A. aspera*. Note distinct growth rings (× 50). **2**, Magnified view of growth ring showing tangentially flattened latewood cells (× 245). **3**, Cross-section of wood of *A. indica*. Growth rings absent (× 50). **4**, Cross-section of wood of *A. aspera* showing tangential rows of vessels (arrows) (× 100). **5**, Scanning electron micrograph of vessel wall with vestured pits Arrow shows the view from the outer surface. On the right is the condition seen on the inner surface of the vessel (× 2825). **6**, Surface view of the vessel wall. Note pits with reduced borders (× 900). **7**, Vessel wall with transitional types of pits (× 900). **8**, Scanning electron micrograph showing helical thickening on the vessel wall surface, as viewed from the inner surface (× 3345). **9**, Scanning electron micrograph showing portion of vestured vessel element wall (× 4040).

Figure 10–21. **10**, Paratracheal axial parenchyma in *A indica* in cross-section. Arrow points to nucleus (× 120). **11**, Paratracheal axial parenchyma in longitudinal section. Arrows point to nuclei (×.180). **12**, Crystals in the segmented parenchyma cells (× 335). **13**, Radial longitudinal section showing homocellular rays (× 160). **14**, Tangential longitudinal section showing fusiform wood cells (× 100) **15**, An instance of occurrence of radial vessel in the ray (× 275). **16**, Cross-section of wood with fibres in association with vessels (arrow) (× 160). **17**, Longitudinal section of wood. Note the intrusive growth of fibres (× 180). **18**, Cross-section of wood showing abundant pits on the end walls of fusiform wood cells (× 435). **19**, Scanning electron micrograph of fusiform wood cells bearing a large number of pits on the end walls (× 1240). **20&21**, Scanning electron micrographs of fusiform wood cells. Pits are absent on the tangential longitudinal walls. (**20**, × 1075; **21**, × 890).

by thin-walled fusiform wood cells is mainly responsible for making this the lightest wood known.

The structure of sola wood provides the basis for being an ideal material for traditional art work where softness, lightness and resiliency are required. Sola can be easily cut, peeled, stretched and bent owing to the presence of abundant fusiform wood cells. The air-filled cells account for the insulating property of the wood. The wood of *A. aspera* is easier to peel than that of *A. indica*, a property that could be attributed to the presence of distinct growth rings in the former.

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Is pH(i) a factor for dormancy in freshwater fairy shrimps?

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***Cellular dormancy* is a common event in the life cycle of lower crustaceans, especially in brine shrimps and fairy shrimps. We have studied termination as well as initiation of cellular dormancy in the cryptobiotic cysts of a freshwater fairy shrimp *Streptocephalus dichotomus* by elevating the internal pH optima of the cysts. Experimental evidences clearly indicate that alkalinization had no significant effect on the termination of dormancy, but subsequently no hatching occurred. Thus the dehydrated gastrula, containing approximately 4000 cells, undergoes dormancy with environmental adversity combined with physiological status of the growing embryo. The cysts of fairy shrimps, thus, do not come under the category of either aerobic or anaerobic dormancy as described for the brine shrimp *Artemia* sp.**

In the brine shrimp *Artemia* sp. hypometabolic status is regulated, at least in part, by moderate alkalinization of intracellular pH [pH(i)]. In the brine shrimp *Artemia*, larger pH(i) changes bring meaningful conditions accompanying transitions between profound dormancy (cryptobiosis) and development in encysted gastrulae stage embryos (cysts)[1]. Similarly, an increase in pH(i) accompanies the transition between dormancy and development in the sea urchin.

Under natural environs, the cysts remain developmentally arrested even in the presence of atmospheric oxygen. Accordingly, Busa and Crowe[1] classified the dormant cysts of *Artemia* into aerobic and anaerobic dormant types based on O_2 and CO_2 availability respectively. It is known that changes in pH(i) accompany the reversible transition between aerobic development and anaerobic dormancy.

Based on the foregoing account on the influence of pH(i) optima in development, we also tested the effect of intracellular alkalinization on the cryptobiotic cysts of the fairy shrimp *Streptocephalus dichotomus*, using weak bases, as outlined by Busa *et al.*[2]

It is well known that a majority of anostracan crustaceans (fairy shrimps and brine shrimps) are adapted to a life in intermittent aquatic environments, and hence they produce encapsulated, dehydrated gastrulae, called cysts. Each cyst contains ca. 4000 morphologically undifferentiated embryonic cells[3] (Figure 1).

Elevation of the internal pH of the cryptobiotic cysts of *S. dichotomus*, by incubating in NH_4Cl (0.1 μM) as well as in $(NH_4)_2SO_4$ (40 μM), had no significant effect on their dormancy, although the cysts were kept for 30 days of observation (Table 1). On the other hand, cysts kept in Cairns' medium showed hatching within 24 h of incubation (Table 1). This may clearly suggest that these cysts do not come under the category of either aerobic or anaerobic dormancy like *Artemia*. Hence the initiation of the dormancy is thus coupled with environmental adversity combined with physiological status of the growing embryo[3].