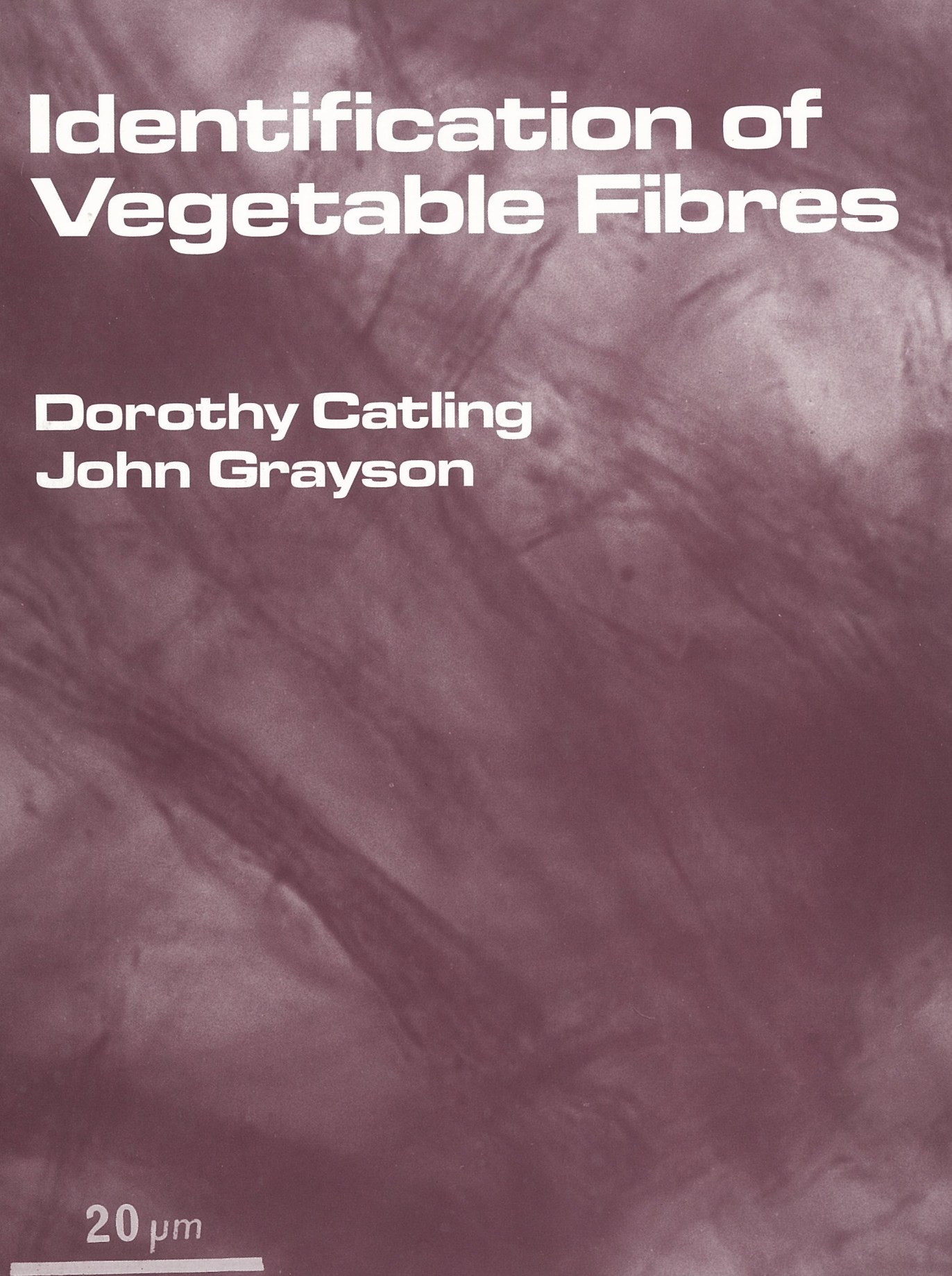
Identification of Vegetable Fibres

Dorothy Catling
John Grayson



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CONTENTS

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1
INTRODUCTION

It is often possible to identify fragments of plants by studying their microscopical characteristics. The recognition of a single feature very rarely establishes the plant's identity; more often, it is necessary to recognize a unique combination of characteristics. For plant identification, the most valuable characteristics are those least likely to be affected by changes in environment; if the feature is uncommon as well as stable, it is even more useful.

Good descriptions of the anatomy of plants are invaluable. For example, *The Identification of Hardwoods* (Brazier and Franklin, 1961), together with its punched card key, is an excellent book which is useful in practice. Characters describing the sclerenchyma account for only three places in this key. Using only these characters, it would be impossible to identify a timber. Is it possible then, to identify a species given only sclerenchyma in the form of a commercial fibre? If it is possible, it is not easy.

Although, for many purposes, plant fibres are being replaced by man-made fibres, vegetable fibres are still used, particularly in sacking and cordage and in some industrial materials. Articles which must be examined in a forensic science laboratory are not always of recent manufacture and archaeologists and historians are interested in older materials. Therefore, it is still necessary for many workers to identify the plant species from which fibres have been extracted.

Unfortunately, reliable information is not readily available and has not been collected together in one work. In many publications, the information which is given is wrong. Therefore, this work begins by evaluating the characteristics which have been put forward as reliable for fibre identification, by exploding some old myths and by suggesting some characters which might be studied to good effect.

DISLOCATIONS

According to Tobler (1957), the term 'dislocations' and the first descriptions of these displacements in sclerenchyma cells are attributable to von Höhnel (1884), who wrote of 'ring markings' which occur as a result of 'tension in the tissues'. In contrast with the ideas of von Höhnel, Schwendener (1894) said that dislocations did not occur naturally but were artificially produced. Almost a century afterwards, Freund (1972) wrote of the difficulties experienced in explaining the cause of dislocations. In the course of this

work, many fibre cells have been studied and the similarities are impressive between the dislocations in the walls of fibre cells and the slip planes which, in the walls of soft wood tracheids, are associated with compression failure (Dinwoodie, 1968). Discussions with wood scientists have led to the suggestion that dislocations in fibre cells are regions where the wall has suffered damage by compression. This can occur as the plant grows. Frey-Wyssling (1934) studied their structure using polarized light, and Rahman (1979) showed them with the scanning electron microscope. Whatever the cause, there is no doubt that dislocations occur in every species examined during the course of this work. It is most probable that Tobler (1957) is correct when he writes that, in the light of investigations, 'The significance of dislocations for diagnostic purposes has completely disappeared.'!

FIBRE CELL ENDS

Many authors, for example Hanausek (1907), Matthews (1931) and Koch (1963), have described the shapes of the ends of sclerenchyma cells and have suggested that the information is useful in the identification of the species. In Plate 3 a number of different end shapes can be recognized. All of them are the ends of cells of *Linum usitatissimum*. It will be appreciated, therefore, that this is not a very useful character for the identification of plant fibres.

In this work, a series of shapes is defined (Fig. 1) and used in describing each species.

CELL WALL AND LUMEN

In the work of Brazier and Franklin (1961), the thickness of the cell wall which is defined by reference to its complementary feature, the size of the lumen, is used in the identification of timber. Wall and lumen features are frequently referred to when

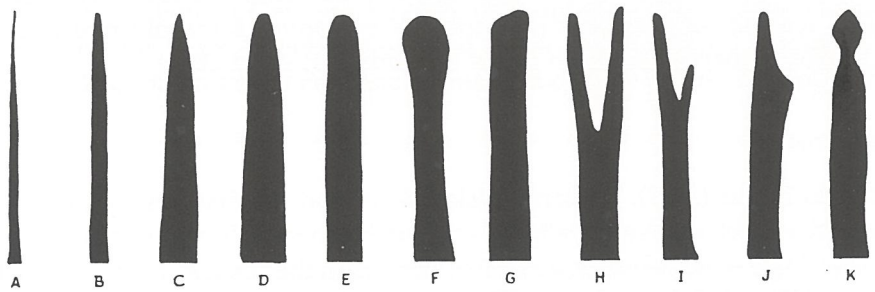

Fig. 1 Fibre cell end shapes. A, Tapering and pointed; B, tapering and rounded; C, pointed; D, Bluntly pointed; E, rounded; F, spatulate; G, square; H, bifurcated; I, unequally bifurcated; J, scimitar-like; K, constricted.

commercial vegetable fibres are described (e.g. von Wiesner, 1927, and Hanausek, 1907).

The heartwood is the product of several seasons' growth. The region of active growth and differentiation, in the sapwood, close to the cambium, is only a small part of the xylem and is often lost during the preparation of the timber. On the other hand, vegetable fibres are the products of a limited period of growth. In a leaf or in a stem where there is cambial activity, cells which have not achieved their final form will be relatively more common. If a linen fibre cell has not completed the laying down of the cell wall, the lumen will be wide, not narrow as it is, characteristically, in a mature cell. A jute cell in which the wall is only partially formed might not show the variations in the lumen width which are often quoted as a valuable diagnostic feature. The conditions under which the crop has been grown can affect the properties of the plant cell wall. Nevertheless, used carefully, this is a very useful feature.

Descriptions of pits are used by Brazier and Franklin (1961), and, in vegetable fibre also, this feature gives useful information.

CRYSTALS

The presence and distribution of crystals or silica can be useful in timber identification (e.g. Brazier and Franklin, 1961, and ter Welle, 1976), although their absence is not necessarily a diagnostic character. The forms and distributions of crystals and silica are useful in the identification of vegetable fibres. Jarman and Kirby (1955) wrote of 'The differentiation of jute and some jute substitute fibres on the types of crystal present in the ash'. Crystals have never been reported in *Linum usitatissimum* but, with this exception, the crystals or silica of all the species studied yield useful information. Characteristics observed in section can be recognized in samples of fibre and in ashed specimens.

CELLS FROM TISSUES OTHER THAN SCLERENCHYMA

The possibility of identifying a plant by the study of one tissue, the sclerenchyma, has been considered. However, vegetable fibres are not always processed so thoroughly that every part of the adjacent tissues is removed and it is possible to find cells which give clues to the structure of the organ from which the fibres were taken.

CROSS MARKINGS

In each of the descriptions of individual species, a section is headed 'Dislocations and cross markings'. Tobler (1957) wrote 'How far they (the dislocations) might be confused with circumstances of attached wall remains of neighbouring-cells must not be forgotten.' In the present work, dislocations are recognized. The term 'cross markings' is

applied to 'the attached wall remains of neighbouring cells' or to the impressions on the fibre cell wall made by neighbouring cells which have been removed during processing. A consideration of these features can provide information about the whole structure from which the fibres have been taken. Sometimes, the cross markings are extremely faint and have the appearance of very fine septa which cross the cell but, unlike a septum, a mark is not limited to the cell lumen. Sometimes, the marks cross the whole cell, at others they cross only part of the cell; it is possible to have more than one series of impressions on one fibre cell. As well as very fine cross marks, much more pronounced marks occur, sometimes with an accompanying distortion of the cell wall, and, in extreme examples, it is difficult to differentiate between a cross mark and a dislocation. Perhaps it is reasonable to suggest that compression failure will be less likely to occur where fibre cells form a block of strengthening tissue than at the boundary between two tissues. Some association between dislocations and cross markings is recognized and it is appropriate to describe them under one heading.

THE APPEARANCE OF FIBRE CELLS IN TRANSVERSE SECTION

In this work, the shapes of fibre cells in transverse section are discussed in the descriptions of stems and leaves. In examining sections of these organs, it is found that the shapes of fibre cells sometimes vary with different conditions of growth. Also, the precautions necessary to prevent distortions can make the sectioning of an extracted group of fibre cells from a strand of commercial fibre a tedious task. However, with these provisions, a study of the shape in transverse section can sometimes help in the identification of a fibre.

FIBRE CELL DIMENSIONS

Many measurements of the lengths and widths of fibre cells have been made. These are presented and discussed in the Appendix.

SECTIONS OF STEMS AND LEAVES

It is suggested that in order to understand the anatomical characteristics of plant fibres it is necessary to study the organs from which they have been taken. For this reason, drawings and descriptions of sections are included in this work. The descriptions are based on observations. Where these observations vary markedly from those of other authors, attention is drawn to the differences.

TERMINOLOGY

In the past, confusion has arisen because one expression has been given different

meanings by different workers. Particularly, some words have come to mean different things to botanists and to those in the fibre trade. The following definitions apply in this work.

Fibre: fibrous material which has been extracted from a plant.

Fibre cell/sclerenchyma cell: one of the individual cells of which the fibre is made up. These cells are sometimes called ultimates or ultimate fibres (e.g Kirby, 1963).

Specimen: an individual reference sample of fibre.

Occasionally, a description is repeated so that it occurs in more than one place in the text. This has been done because some characteristics should be considered in more than one context.

2
MATERIALS AND METHODS

MATERIALS

The fibre specimens used for this work were from the Tropical Products Institute's reference collection, which was mostly kindly given to the Metropolitan Police Forensic Science Laboratory.

As well as fibre specimens of each species being examined, sections of stems and leaves were prepared. Whenever possible, material from several sources was sectioned and studied.

A list of the materials examined precedes the description of each species.

METHODS

Lengths of approximately 100 mm from the centre of a fibre hank from each specimen were treated in the following ways:

Before the fibre was prepared in any way, it was examined and its texture and colour noted.

Samples of fibre were boiled in water to remove air and mounted on microscope slides in 50 per cent glycerin.

Samples of fibre were macerated. The sample was put into a conical flask containing a mixture of equal parts of glacial acetic acid and 20-volume hydrogen peroxide and heated on a water bath for 7 or 8 h. The fibre sample was then transferred from the macerating fluid to water, and the container was vigorously shaken so that the fibre strands separated into individual cells. The cells were mounted in 50 per cent glycerin for microscopical examination.

This method is gentle and suitable for small samples.

Some of the macerated cells were stained with a 1 per cent aqueous solution of Chlorazol Black. To do this, it was necessary to centrifuge the samples for 20 min at 2000 rev. min^{-1} and pour off the supernatant, before adding the stain. After the samples had been staining overnight, the centrifuge was again used to remove surplus stain and to wash the samples several times with distilled water. Stained cells were mounted in 50 per cent glycerin.

Samples were ashed. The fibre sample was put into a small porcelain crucible, with a lid, heated in a muffle furnace at 600°C for 3–4 h and allowed to cool. The ash was

transferred to a microscope slide and mounted using Depex or 50 per cent glycerin. The sample was moved and mounted carefully, disturbing the ash as little as possible.

Stems, pseudostems and leaves were preserved in formalin acetic alcohol and stored for some weeks before use. The specimens were washed in running water for several hours before sections, approximately 20μm thick, were cut using a Reichert OME microtome. The material was not embedded but was held in the Naples clamp of the microtome. Sometimes it was necessary to support stems or leaves with pith or cork.

Sections were stained with a mixture of safranin and haematoxylin according to the method of Metcalfe (1960). Before staining, some sections were cleared using a domestic bleach such as Parazone as described by the same author.

Stems, pseudostems or leaves which had been dried were revived according to the method of Metcalfe (1960).

Epidermises from stems, pseudostems and leaves were prepared and stained as described by Metcalfe (1960).

Dimensions of fibre cells in macerated specimens were measured using apparatus at the Commonwealth Forestry Institute, Oxford. Lengths were measured using a magnifying projection microscope and a map measurer, connected to an automatic counter. Widths were measured using a shearing eye piece, which was also used with an automatic counter (Hughes and Andrews, 1974).

Photomicrographs taken by phase-contrast microscopy were used to prepare Plates 3–26 and 43–48. Individual photographs were cut out and mounted side by side to show the *range* of variation of each characteristic.

THE USES OF VEGETABLE FIBRES

Considerable quantities of jute, flax and sisal are imported either as raw fibre or as manufactured items. Table 1 is probably incomplete, but it gives some information about the common uses of these fibres.

At the present time, abaca, hemp, sunn hemp and ramie are less often used than jute, sisal and flax, but are still made into cordage of all kinds.

As well as the uses listed, plant fibres are frequently constituents of paper. Linen and abaca, particularly, are traditionally used to make strong and durable paper.

THE CULTIVATION AND EXTRACTION OF FIBRES

The fibres which are described are either bast fibres, taken from the outer part of the stem, or leaf fibres, taken from the leaf or leaf base. In commerce, the former are described as soft fibres and the latter as hard fibres. Soft fibres are derived from dicotyledons and hard fibres from monocotyledons. Of the ten species which have been studied, two, sisal and abaca, are leaf fibres and eight are bast fibres.

Table 1. The uses of jute, sisal and flax

Jute	*Sisal*	*Flax*
Sacks	Sacks	Fabric for clothing
Baling material	Ropes	Household linen
Ropes	Yarn and cordage for many purposes	Buttonhole twist
Yarn and twine for many purposes, e.g. horticultural twine	Furnishing fabrics	Button thread
Wrapping and braid in cables	Wallpaper	Industrial fabrics
Tarpaulins	Matting	Canvas – especially when wet strength is needed
Roofing felt	Reinforcing materials also with other materials such as rubber	Hosepipes
Carpet backing	Tea bags	Mailbags
Linoleum backing		
Furnishing fabrics		
Upholstery lining		
Tailors' canvas		

For the most part, soil conditions are less important than some other factors in the production of successful fibre crops, although most plants prefer soil which will drain well in wet weather and will not dry out during periods of low rainfall. For some fibre crops, rotation is considered important. The attention to the application of fertilizers varies from place to place. To a large extent, such things will depend upon the wealth and skill of the farmer.

For crops grown from seed, it is important that the ground should be carefully prepared and that there should be sufficient rainfall at the time of sowing to allow germination. In tropical countries, the sowing of the crop is often timed to coincide with the beginning of the rainy season. It is necessary to keep the seedlings free from weeds but, once the plants are established, this is less important, although weeds can interfere with retting, and the growers of flax particularly try to keep the crop clean throughout its growing period. Of the ten species described, jute, kenaf, roselle, flax, hemp and sunn hemp are grown from seed. Ramie can be grown from seed but it is more usual for it to be propagated from stem cuttings or from sections of rhizomes. Sisal is propagated by growing the small bulbils which develop in the axils of peduncles, and abaca is propagated by root cuttings or from suckers which arise at the base of the plant.

Once abaca is established, the first cutting of the pseudostems can be taken within 2 or 3 years, but it will be a little longer before the plant will give a maximum crop of good quality fibre. Having reached maturity, the yield will be maintained for 5 or 6 years before it begins to decline. After 12 or 14 years it is generally considered advisable to replant. *Musa textilis* requires a certain minimum rainfall and humidity. In its native environment, *Agave sisalana* can live for 20 years, although in the climates to which it

has been introduced the life is often shorter. *Agave* is a xerophytic genus which is able to withstand periods of drought, although it is in the wet season that the plant produces new leaves. The stems of the eight species grown for the production of bast fibres are harvested after a period of growth of only a few months, generally between 3 and 5 months. Ideally, during this growing season, the crops require an even temperature and a humid atmosphere so that, throughout the whole period, there is regular and uninterrupted growth.

The spacing of plants is important. When seed is sown, sufficient must be used. The crowded seedlings support and shelter each other and the growth of weeds is discouraged. Later, the plants are thinned but they are still grown close enough to encourage tall straight stems and an unbranched habit. Spacing is important in plantations of *Agave*, and experiments have determined relationships between plant density and fibre yield. The number of plants which an hectare will support and the arrangements of plants within the crop vary from place to place according to climate and local custom (Kirby, 1963). Spacing is also important in growing *Musa textilis;* it is often the practice to intercrop with a leguminous species to fix nitrogen and to cover the ground between rows.

In growing all plant fibres, the success of the crop will depend to a very large extent on the skill of the farmer in deciding when the harvest should be gathered. If the crop is harvested too early, the yield will be low, but, if harvesting is delayed for too long, the quality of the fibre will probably deteriorate. For example, if growth is prolonged, bast fibres often become lignified. Also, difficulties experienced in separating the fibre from other tissues and in processing them can often be traced to excessive delay in harvesting. Frequently, the time for harvesting is associated with the flowering of the plants; other changes such as the fall of some leaves or flowers or changes in the colour of some parts of the plant can provide a guide to the condition of the plant. Ultimately, it is the judgement of the grower which will determine the quality and yield of the fibre. In the cultivation of *Agave sisalana*, careful cutting (removing enough mature leaves to stimulate new growth) is most important. If the plants are cropped too drastically, the yield of fibre will be reduced in subsequent growths.

Once the plants have been harvested, the fibre must be separated from unwanted tissues. Generally, in the case of bast fibres, soft tissues are broken down by the action of micro-organisms during retting; this is followed by scutching to remove debris. In retting, as in harvesting, personal judgement plays a vital part. If the process is continued for too long, the fibre cells also will be affected by the action of the organisms and will be weakened, but retting for too short a time will make it difficult to separate extraneous material. Ramie is cleaned by a decortication process somewhat similar to that used to extract the hard fibres. Some specimens of other bast fibres have also been cleaned without retting; producers are always willing to consider methods which will reduce the time and expense involved in refining the fibre. There are many local variations in the methods of retting and decortication. The mechanization of these

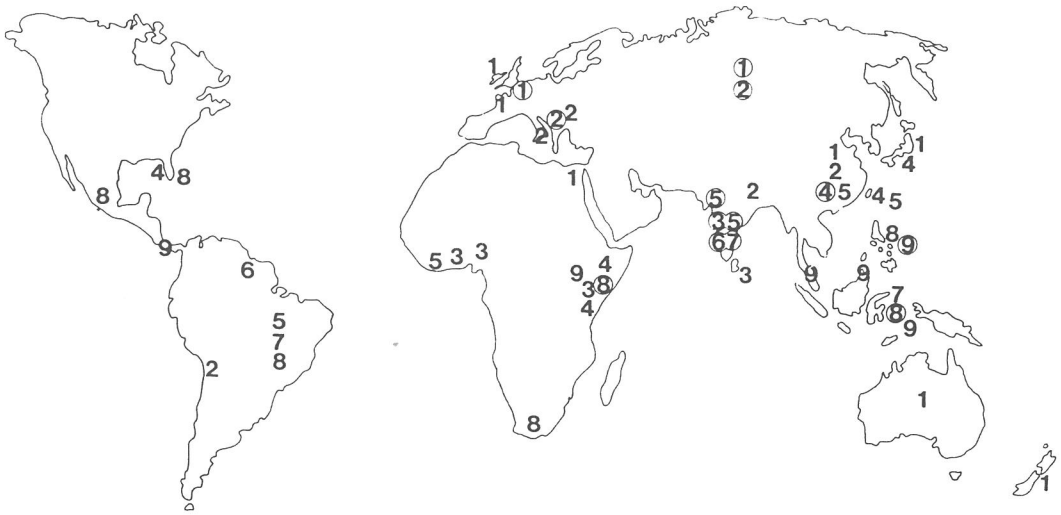

Fig. 2 Principal centres for fibre production. 1, Flax; 2, hemp; 3, sunn hemp; 4, ramie; 5, jute; 6, kenaf; 7, roselle; 8, sisal; 9, abaca. ⓝ Most important countries for the production of the fibre. *n* Centres of secondary importance

processes might depend upon the wealth of the farmer or upon the availability of central processing stations. The provision of an adequate water supply and the disposal of waste are problems which have to be overcome. Once extracted and cleaned, the fibres are baled and graded.

Like most plants of commercial importance, fibre plants have been studied by plant breeders. As well as experiments to produce new varieties, trials have been carried out to study conditions which might affect the growth of plants and the production of fibre. For example, Khan, Khan and Hashmi (1968) studied the lengths of fibre cells under different treatments, Rao and Kundu (1955) the effect of maturity on the dimensions of fibre cells, Yanagisawa (1970) the response to different day lengths and to shading (Yanagisawa 1967), Valynats and Mashtakow (1963) the reactions of flax to treatment with herbicides, and Petrova-Alexandrova *et al.* (1959–1963) the effects of mineral fertilizers, retting and moisture in the soil.

Although, in the species studied during the course of this work, differences between specimens have been noticed, without a complete record of the history of the crop it is not possible to know what caused these differences. They might be the result of a single factor or of many different combinations of factors. It is unlikely that such information will be available for commercial specimens. In some of the sections examined, there are differences between plants of the same species grown in botanic gardens and plants grown for fibre. Generally there is less parenchyma in stems grown as fibre crops, and the sclerenchyma cells are more closely packed and sometimes are more angular in

transverse section. In many cases, the thickness of the fibre cell walls is more uniform and there are fewer thin-walled cells. However, these observations are based on too few examinations to suggest that they have general significance. It is necessary to be aware of the situations in which fibre cells occur in the living plants and of variations which can occur, although the combination of characters which is used to identify the species is not fundamentally altered by different environments.

Fig. 2 shows the principal centres for fibre production.

3
FLAX
(*Linum usitatissimum* L.)

Fibre specimens examined:

Reference number	*Origin*	
J1/52	H.M.N.F.E.*	Green flax
J9/60	H.M.N.F.E.	
J7/58	H.M.N.F.E.	Raw flax
J3/54	Northern Ireland	Green fibre, rolled and scutched
J5/56	Cyprus	Batalika grade. Native variety 1926 crop. Straw.
J6/57	H.M.N.F.E.	Raw flax
J4/55	Borneo	Unretted, crimped and scutched
J4/55	Borneo	Purified flax
J8/59	Northern Ireland	Green flax, scutched
J2/53	Northern Ireland	Tow

Additional samples from The Linen Industry Research Association, Lambeg, Lisburn:

1.	Northern Ireland	
2.	Belgium	Water-retted
3.	Northern Ireland	Green
4.	Southern Ireland	Linron
5.	France	Dew-retted

Stem material sectioned and examined:

1. Stems from plants grown in the Royal Botanic Gardens, Kew, harvested in 1972.
2. Stems from plants grown in the Royal Botanic Gardens, Kew, harvested in 1976.
3. Stems from The Linen Industry Research Association, Lambeg, Lisburn, Northern Ireland.
4. A commercial sample of flax straw from the Tropical Products Institute collection, No. J5/56.

* His Majesty's Norfolk Flax Establishment. This organization ceased to operate in the early 1950s.

Flax is a member of the family Linaceae which has 12 genera. The genus *Linum* has 230 species. Only *L. usitatissimum* is of great commercial importance; it is the source of flax and, also, of linseed. The two products are not collected from the same crop. Varieties which yield high-quality fibre do not produce a good harvest of seed, and methods of cultivation differ according to the purpose for which the crop is grown.

L. usitatissimum is an annual. It grows to a height of approximately 1 to 1.3 m. The stem has a diameter of 4 or 5 mm. The stem and leaves are glabrous. The leaves are alternate, attenuated and lanceolate, and the flowers, which are white, blue or purple, are borne on loose terminal racemes or open cymes.

THE ANATOMY OF THE STEM

The epidermis has a well-developed cuticle. In surface view, the cells have from four to six sides; the two long sides are parallel to each other and to the axis of the stem. Stomata are paracytic (rubiaceous); each is accompanied by two subsidiary cells, one on either side, parallel to the guard cells.

The layer of cells below the epidermis is not uniform but consists of chlorenchyma cells and larger more or less empty cells which occur either singly or in groups. In stems grown in the Royal Botanic Gardens, Kew, the large empty cells account for the greater part of the subepidermal layer, but, in stems grown as fibre crops, they are rare. Without carrying out developmental studies, it is not possible to say whether the plant has a true hypodermis or a multiple epidermis.

The outer cortex consists of two to four layers of chlorenchyma. Below this, the pericyclic fibres occur; these are the commercially important flax fibres. Groups which contain from 20 to 80 fibre cells are separated by narrow girders of parenchyma cells. These girders connect the cortex with a less well-defined region of parenchyma which merges with the phloem. Very occasionally, single large parenchyma cells are found amongst the fibre cells. An endodermis is not well defined, although, in places, between the cortical chlorenchyma and the sclerenchyma, a single row of morphologically differentiated cells can be recognized.

The phloem consists of sieve tubes, companion cells and phloem parenchyma. In mature stems, the phloem and xylem form a continuous cylinder, crossed by narrow medullary rays. A well-defined cambial zone is recognizable between the phloem and xylem.

The xylem is composed of vessels, tracheids, fibre tracheids and xylem parenchyma. Macerated stems show a range of cells in which many intermediate forms can be recognized. Perforations are simple. In young vessel elements pitting is sometimes in axial files, but, in mature vessels, the pitting is alternate. Towards the protoxylem, radial multiples predominate and axial elements show a tendency to be storied.

The centre of the stem is filled by pith. In older plants these cells break down and the stems become hollow.

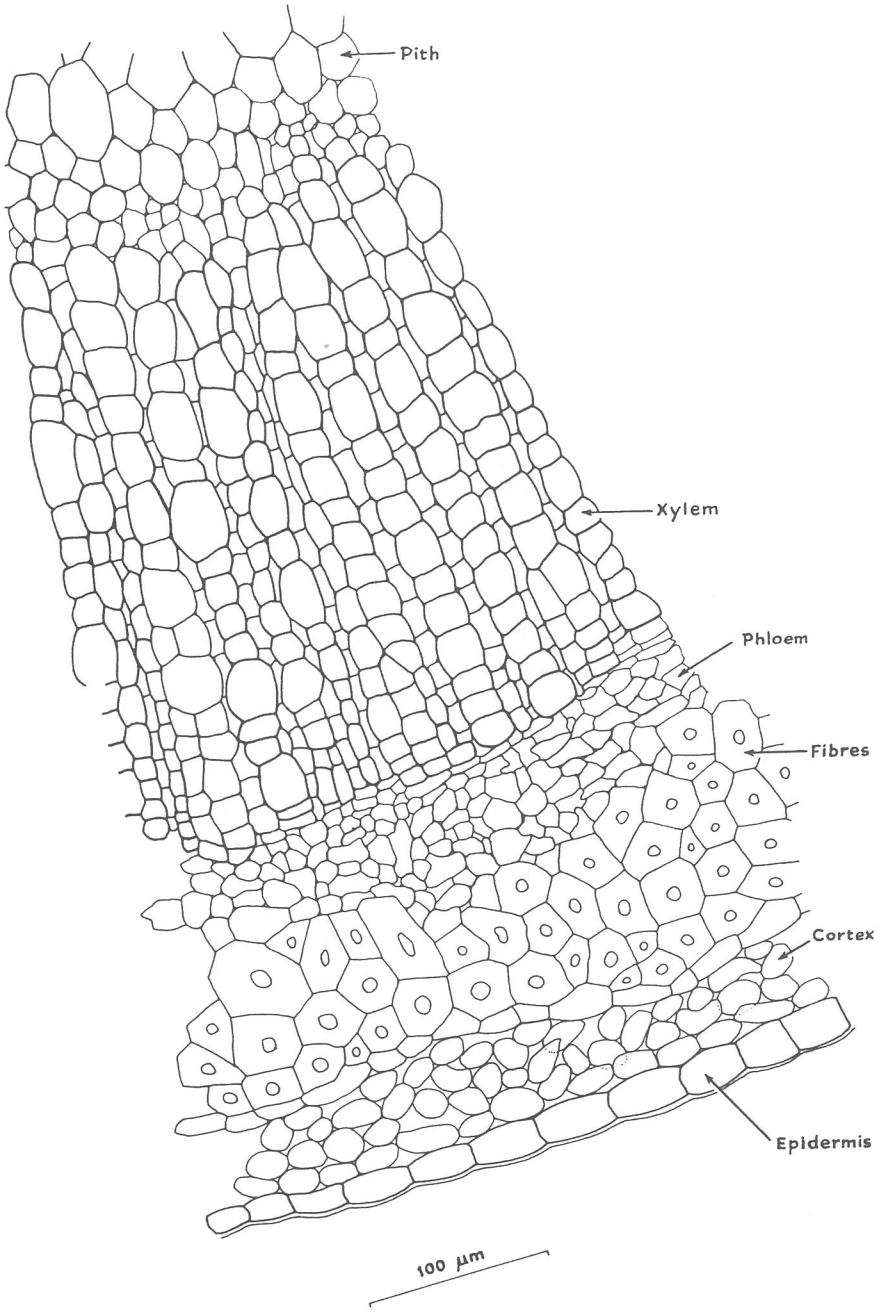

Fig. 3 *Linum usitatissimum* L. Transverse section of stem

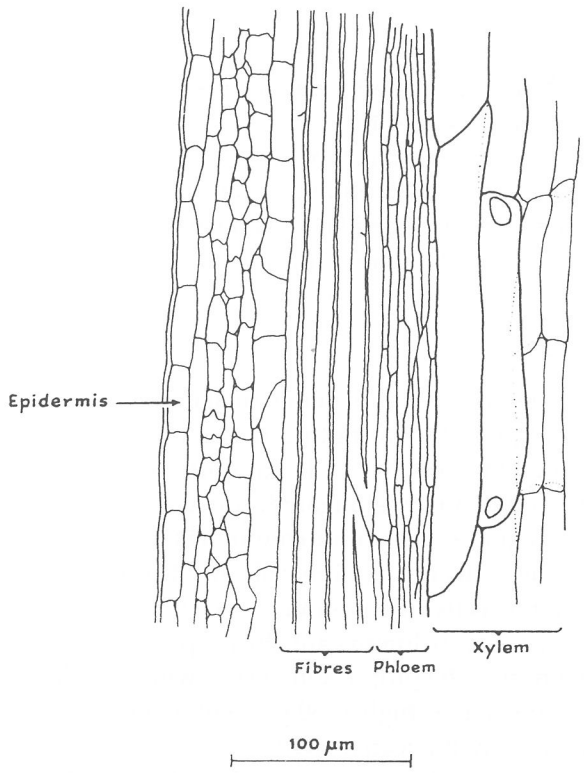

Fig. 4 *Linum usitatissimum* L. Longitudinal section of stem

In sections from crop plants there are fewer large empty cells in the subepidermal layer than in those from plants grown in botanic gardens. Also, in fibre crops, the numbers of cells in the fibre bundles are much greater, rather less parenchyma is produced and the cambial zone is less well developed.

Hayward (1938) reports the presence of a well-defined hypodermis and writes 'The cells are similar to the epidermis but are much smaller and thinner walled. The hypodermal cells contain chloroplasts'. This does not entirely agree with the observations made during the course of this work. The same author also records the presence of a well-defined endodermis.

APPEARANCE AND TEXTURE

Flax is one of the finer commercial fibres and is seldom very hard or coarse in texture; at its best it is fine and silky. Its colour varies from white or grey to bright light brown. The lowest-quality fibre, the tow, is more coarse, is often grey brown and contains large amounts of stem debris.

FIBRE CELL ENDS

Tapering and rounded or tapering and pointed ends are most common, and both types occur in large numbers in every specimen; in all the specimens, except one, the tapering rounded shape is most frequent. Many tapering pointed cells have fine thread-like tips. In each specimen, some rounded, bluntly pointed and pointed ends are found. Bifurcated, unequally bifurcated, scimitar-like and constricted ends are rare. Specimens in which these occur are generally less uniform.

LUMEN AND CELL WALL

In transverse sections the fibre cells are pentagonal or hexagonal and slightly rounded in outline. The cell walls are of uniform thickness and, typically, the wall is about six times as wide as the lumen. However, it is not unusual to find cells which have thin walls and wide, often tangentially elongated, lumina. Particularly, cells of this type occur near the cambial region and are more common in plants grown in botanic gardens than in crop plants. The walls of the fibre cells are distinctly laminated.

The appearance of the cells in macerated specimens is consistent with that in sections. Cells with very narrow lumina are always present but so, also, are cells with thin walls and wide lumina. The proportion of cells with wide lumina varies considerably and, in two specimens, is as high as 50 per cent. Generally the lumen has an even width, but very occasionally it is constricted.

There are fine pits with slit-like apertures in the cell wall, although they are not an obvious feature; sometimes they can be seen more clearly if the specimen is examined with polarized light. It is not always easy to differentiate between pits and other irregularities on the cell wall. Longitudinal striations can be seen in some cell walls. Occasionally, cells show cross checking.

Hanausek (1907) described the individual fibre cells as 'Sharply polygonal with five or six straight sides', but observations made during the course of this work suggest that a more rounded outline is most usual.

DISLOCATIONS AND CROSS MARKINGS

Dislocations occur frequently and are a very conspicuous feature. Cross markings are few and faint. Fibre cells occur in large groups and only those which are adjacent to parenchyma cells have cross markings. Occasionally cells have evenly spaced marks along their whole length. Sometimes, cells carry the deep impressions of parenchyma cells along one side.

CRYSTALS

The presence of crystals is not reported by any author. No crystals were found in any of the specimens examined.

CELLS FROM TISSUES OTHER THAN SCLERENCHYMA

Many grades of fibre are used for many different purposes and the care with which the fibre is cleaned is very variable. In nearly every specimen, epidermal cells with typical paracytic stomata are found. Parenchyma cells from the cortical region are frequently present. In most specimens, cells from the xylem occur. Within the xylem there are four types of cells and, between these, there is a graded series of forms. Vessels have simple perforations. In some elements the pitting is arranged in axial files but, in others, it is alternate. Spirally thickened vessels from the protoxylem are found in many specimens.

4
HEMP

Cannabis sativa L.

Fibre specimens examined:

Reference number	*Origin*	
E2/24	Italy	
E3/25	Italy	
E4/26	Lewes, Sussex, UK	
E1/23	Yugoslavia	
124/1906	Italy	From W. Wigglesworth & Co.
84/1910	China	From Chungking, supplied by G. Asheson via Royal Botanic Gardens, Kew

Stem material sectioned and examined:

1. Stems from plants grown in the Royal Botanic Gardens, Kew.
2. Stems from plants grown in Chelsea Physic Garden, London.
3. Stem material from Pretoria, South Africa, collected by Dr Donald Killick.
4. A commercial sample from the Tropical Products Institute – E4/26.
5. A commercial sample from the Tropical Products Institute – 84/1910.

As well as providing a fibre of commercial importance, the hemp plant is the source of a narcotic drug, and the seeds are used for culinary purposes and as an animal feed. Oil extracted from the seed is a substitute for linseed oil in paint and varnish and is also used in soap-making. Like most plants of economic importance, hemp has frequently been studied by botanists. Its wide distribution, its varying form and its response to environment have been of special interest, and plant breeders have sought to develop strains suited to a particular climate or to the efficient production of one crop. Taxonomists have studied the plant and expressed many views about its affinities and its taxonomic position. It is now agreed that two genera, *Cannabis* and *Humulus*, form the family Cannabaceae and that *Cannabis* is a monotypic genus; Index Kewensis lists only the species C. *sativa* L., an erect dioecious annual which grows rapidly through a comparatively short growing season. A detailed botanical description of the species is given by Stearn (1970).

THE ANATOMY OF THE STEM

Non-glandular trichomes on the stems and leaves of *C. sativa* are either unicellular, thin, curved, more or less warty hairs or thicker unicellular hairs with enlarged bases which often contain cystoliths. On the stems, the bases of the cystolithic hairs are frequently surrounded by a ring of enlarged epidermal cells which stain more deeply with safranin. Rarely, hairs are uniseriate, the basal cell staining less heavily than the terminal cell. At an early stage, cork arises superficially but, even in large well-thickened stems, hairs or the remains of hairs are found.

Stems are more or less ridged, the ridges being composed of collenchyma with weakly thickened walls. The primary cortex, which is continuous, inside the ridges is narrow and consists of a few rows of thin-walled tangentially elongated parenchyma cells. In the outer cortex there are small groups of pericyclic fibres of large diameter with thick weakly lignified walls, but the fibres of the secondary phloem are more numerous; they occur in irregular tangential bands between layers of sieve tubes with companion cells. A group of fibre cells might contain between ten and forty individuals. Within the phloem, laticiferous elements are an easily recognizable feature. Tangentially expanded medullary rays alternate with wedges of phloem and its associated tissues.

Cluster crystals frequently occur in the pericycle, secondary phloem and in the rays; often these are in chambered cells. Specimens which have been grown in such different environments as South Africa and Chelsea Physic Garden also have solitary rhombic and prismatic crystals and these are not confined to the rays but are also in the phloem parenchyma cells, closely associated with the fibres. Rhombic crystals in chambered cells are found very occasionally in the stems grown in South Africa and this feature has also been seen in a stem examined at the Metropolitan Police Forensic Science Laboratory (Roe, 1979).

The cambial zone consists of up to ten rows of cells.

The xylem is a continuous cylinder crossed by medullary rays. Vessels occur singly, in pairs or, less often, in irregular groups of six or more. A radial arrangement of vessels persists in the protoxylem. Vessel elements have simple perforations and somewhat oblique end walls. The vessel wall pitting is bordered, sometimes transversely elongated, is alternate and, where it is crowded, polygonal. Vessel ray pitting is large, simple or with greatly reduced borders, round or gash-like. There is a tendency for axial elements to be storied. Parenchyma is paratracheal and vasicentric. Wood fibres are thin-walled, short and sparsely pitted; the pits are small, slit-like and occur particularly on the radial walls. Rays are high and two or three cells wide with long uniseriate tails; sometimes they combine so that they have the appearance of very high rays with multiseriate parts interrupted by uniseriate regions. Some uniseriate rays occur. In the radial longitudinal section, the rays are seen as composed of upright and, less frequently, square cells.

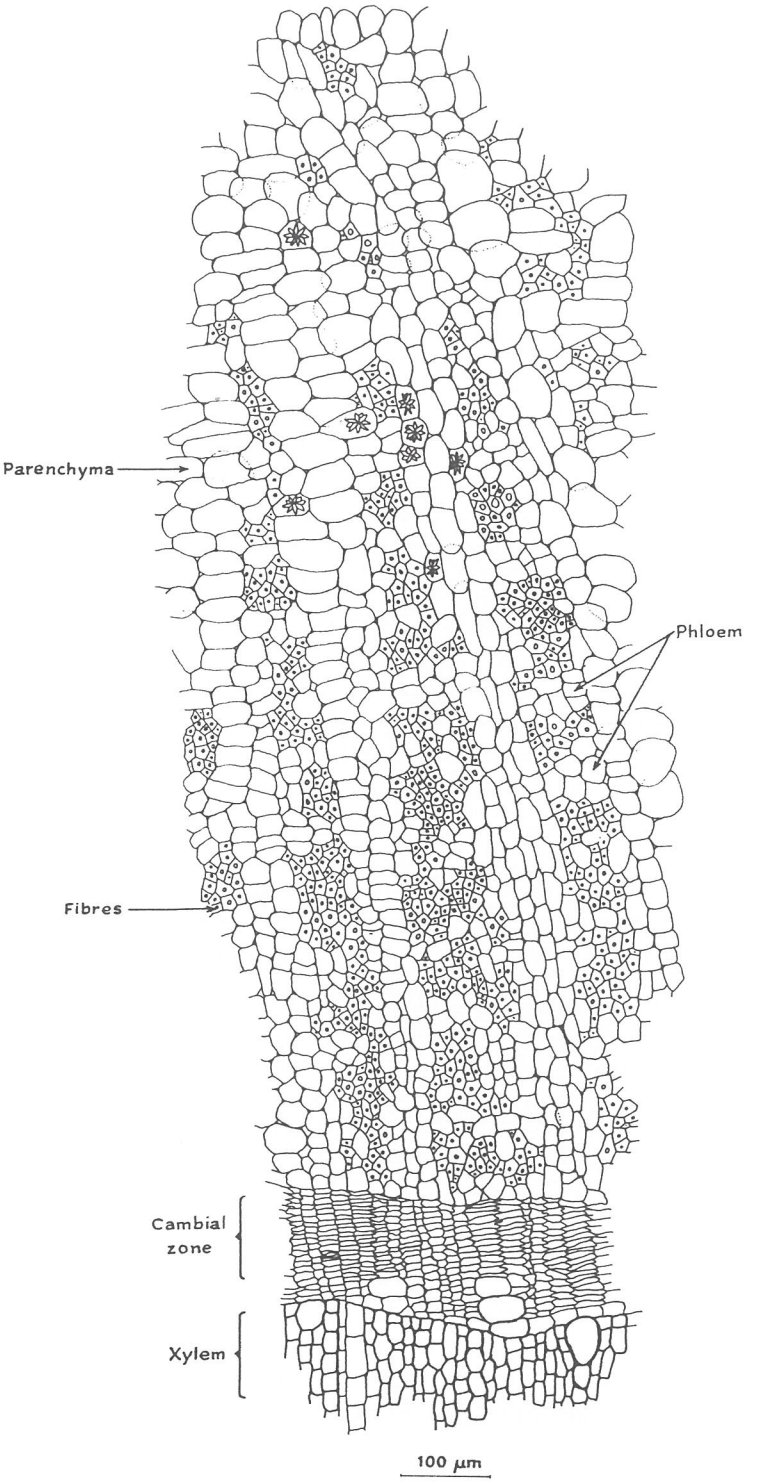

Fig. 5 *Cannabis sativa* L. Transverse section of stem