FURTHER PAPERS

RELATIVE TO THE

PREPARATION OF THE PHORMIUM FIBRE

OR

NEW ZEALAND FLAX.

(In continuatian of Papers presented on 6th October, 1871.*)*

PRESENTED TO BOTH HOUSES OF THE GENERAL ASSEMBLY, BY COMMAND OF HIS EXCELLENCY.

WELLINGTON.

1871.

APPENDIX TO SECOND REPORT OF FLAX COMMISSIONERS.

XV.—FURTHER REPORTS FROM HOME AGENTS.

(Received 16th October, 1871. Continued from page 97 of Appendix to First Report.)

(No. 179).—Mr. Morrison to the Chairman.—24th August, 1871.

With reference to my letter No. 270, 27th July, 1871, I have the honour to inform you that I have forwarded per book post by this mail eight copies each of Dr. M'Nab and Professor Church's Reports on the New Zealand Flax, which have been lithographed, after revision by the reporters. I beg also to state that an equal number of copies will be forwarded by the mail *viâ* Southampton and Suez, on the 2nd proximo.

The originals of the Reports will be handed over to I. E. Featherston, Esq.

(Enclosure).

Report in Reply to Letter from Chairman to Dr. Hooker, of 27th December, 1870. [See Appendix I., p. 2].

Royal Agricultural College,
Cirencester, 31st July, 1871.

Sir,—

In the records of experiments and observations which follow, we have confined our attention to the points of enquiry indicated in the Progress Report of Flax Commission, No. 38, page 19*; and we may here further state, that neither the time given to it, nor the other conditions of the inquiry, has enabled us to treat the subject exhaustively. On this account, the Tables of Breaking Strain could not be undertaken, as this investigation would have necessitated the use of elaborate and expensive apparatus.

The Tables of Contents, prefixed to the accompanying microscopical and chemical reports respectively, will enable the Flax Commissioners to see at a glance the subjects which have been more specially studied by the reporters.

We have, &c.,
W. R. M'Nab, M.D., Edinburgh, &c.,
Professor of Botany.
Arthur H. Church, M.A., Oxon., F.C.S.,
Professor of Chemistry.

Dr. J. D. Hooker, C.B., F.R.S., &c., &c., &c.

* The following were the points suggested for investigation:—

1. Comparative microscopic analysis of the structure of different parts of the fresh leaf:—*a.* Butt; *b.* blade; *c.* tip; *d.* glossy surface; *e.* bloom surface; in each case showing the relative proportions and arrangement of the various tissues in the various parts.

2. Prepared fibres—microscopic comparison of the varieties of *Phormium* fibre, Manilla hemp, Irish flax, Russian flax,—showing relative form and dimensions of the ultimate fibre, and the mode in which they are in contact laterally.

3. Chemical analysis of the proximate constituents of the different parts of the *Phormium* leaf, for the purpose of determining the chemical reaction of the different gummy and extractive matter, and the relative proportion in which these exist in the butt and blade of the leaves. A most desirable point to determine chemically is whether any change analogous to ripening takes place in the juice of the leaf which would indicate the best period for cutting it.

4. The tables of the relative strength of fibres given in books being defective, it is desirable that a series of experiments should be undertaken to determine the breaking strain of all the different kinds of fibre in the market, tested both as straight fibre and when twisted into strands.

5. The investigation of the peculiar action of sea water on rope made of *Phormium* fibre, and the reason for its not absorbing tar, as has been alleged, will naturally form part of the third branch of the subject already indicated.

(Signed) James Hector,
Chairman of Flax Commission.

27th December, 1870.

A.—Microscopic Examination of Phormium Tenax.

Report by William Ramsay M'Nab, M.D., Edinburgh, Professor of Botany in the Royal Agricultural College at Cirencester, England.—July, 1871.

Contents.

§ 1.—General Conclusions.

From the results of the microscopical studies which I have made of the *Phormium tenax*, I conclude—

1. That the best fibres are those which have the smallest cavity, and the greatest thickness of wall.

2. That the fibres at different parts of the leaf are of very different values. As the leaf developes from above downwards, the fibres at the apex will be much older than those at the base. Microscopical examination also shows that the fibres at the base (lower part of the butt) and apex (last inch or two of the leaf) ought to be rejected. The leaves themselves ought also to be very carefully selected.

3. That the fibres situated near the under surface of the leaf are often inferior in quality, and that the microscopic structure of the leaf shows that these bundles can only be separated from the tissues with the greatest difficulty.

4. That no cement exists binding the cells together; the so-called cement of Captain Hutton being the primary cell wall, consisting of cellulose, and easily soluble in chlorate of potash and nitric acid.

5. That the gum existing on the epidermis of the upper surface is not likely to damage the fibres in any way, and can be easily got rid of along with the epidermis.

6. That the differences, chemical and microscopical, between New Zealand flax, and Russian hemp, and Irish flax, render it improbable that the New Zealand flax can ever be profitably applied to the same uses.

7. That the resemblances, chemical and microscopical, between New Zealand flax and Manilla hemp show that New Zealand flax ought to furnish valuable material for the manufacture of ropes, &c. For this end, I would urge that the fibro-vascular bundles be extracted from the leaf as nearly entire as possible, and with care, taking advantage of the cellular sheath surrounding them, this ought to be practicable; but the fibres close to the inferior epidermis ought not to be removed.

8. That as the Natives have overcome all the difficulties, a process as simple as possible ought to be employed, and while the bundles are not broken up into their ultimate cells, every care ought to be taken to preserve the natural oily and fatty matters in the fibre.

§ 2.—Structure of the Butt of the Fresh Leaf.

A.—Lower portion.

The butt, or lower portion of the leaf, may be more accurately described as the ***sheath.*** Microscopically it presents two very different kinds of structure, the basal portion having the tissues arranged in a very different manner from those at the upper portion of the butt or sheath of the leaf.

The basal portion of the butt is generally of a reddish brown colour, and contains a peculiar coloured substance in many of the cells. Besides this colouring matter, very large crystals of *calcium oxalate* were also observed. On section the basal portion exhibits (with a power of about 50 diameters) an upper and a lower epidermis, with a quantity of cellular tissue, while scattered up and down in the cellular tissue the fibro-vascular bundles are seen. The upper superior, or inner epidermis, is composed of minute cells, the outer or free wall not being greatly thickened. Beneath is the cellular tissue of the leaf, the cells of which for a short distance are small and densely packed together. More towards the central portion of the leaf, the cells show well marked intercellular spaces (air spaces or lacunæ) which give a peculiar appearance to the section. The cells are, more or less, regularly arranged in bead-like rows, the spaces or lacunæ between these rows. The intercellular spaces are not equally well marked at every part of the section, in many places the tissue being dense. Towards the inferior lower, or outer epidermis of the leaf, the tissue becomes dense, the cells not presenting evident intercellular spaces. Below the epidermis the cells are small and densely packed together, while the epidermis consists of small cells, with the free surface greatly thickened, and forming a well marked cuticle.

The fibro-vascular bundles are scattered in the cellular tissue between the upper and lower epidermis. These fibro-vascular bundles present two very well marked varieties. Those near the inner or superior epidermis are complete, and made up of numerous tissues, while those near the lower or inferior epidermis are composed exclusively of the *elongated prosenchymatous wood-cells,* which form the fibres of the New Zealand flax. The intermediate bundles sometimes show a kind of transition from the one form to the other, a small inner portion of the bundle being left unchanged into wood-cells.

The different forms of cells making up the fibro-vascular bundle from the inner side of the leaf, can be easily made out by examination with a higher power (250 diameters.) Numerous large openings can be observed in the middle of the bundle, which are the spiral and pitted vessels cut across. On each side of the large openings very small cells are to be seen, the cambiform cells of the bundle; while the thickened prosenchymatous cells of the flax are well developed on the outer or lower side—those on the inner side being only slightly developed. The cells are large, and the walls thin and only slightly thickened.

One of the intermediate bundles shows that the large openings, spiral vessels, &c., are wanting, that the portion of pro-cambium left is very small, the outer prosenchymatous cells being well developed, and forming about 18-20ths of the whole bundle, while the inner prosenchymatous cells are only slightly developed, being represented by only about five or six cells. In the bundles near the outer or inferior epidermis all the procambium has been converted into prosenchymatous cells, each bundle being thus quite homogeneous in structure; no trace of spiral or other vessels being observable. The most characteristic feature of the bundles from the outer or inferior side of the leaf is the large size of the cavity of the cell. The walls are thin, and the size of the cavity shows that the fibres will have comparatively little strength; and also, that owing to the thinness of the walls of the ultimate cells, it will be very difficult to separate them one from the other. The prosenchymatous cells from the bundles on the inner or superior side of the leaf are very different in appearance. The cavity of the cell is very small, and the thickness of the cell wall great. These cells are, however, few in number when compared with the others. The best kind of fibre is therefore very deficient in the lower portion of the butt, while the inferior fibres are abundant.

The parenchymatous cells at the base of the leaf contain more or less protoplasm and nuclei; but no chlorophyll was observed in the cells.

The epidermis of the upper or inner surface of the leaf has only a very slightly developed cuticle, while the epidermis of the lower or outer surface is made up of cells of small size, much thickened on the free surface, and covered with a very thick cuticular layer.

In the lower part of the butt of the leaf the cellular tissue largely predominates, forming about 3-5ths or 4-5ths of the whole. The fibro-vascular bundles vary much in character, some consisting entirely of the prosenchymatous cells, others containing only a few: The large size of the cavity of the prosenchymatous cells shows that they will possess but very little strength; and also, that there will be very great difficulty in separating these ultimate cells on account of the thinness of the wall.

The fibres from the lower part of the butt cannot be considered to be of good quality and probably it will be found best in preparing the fibre for manufacturing purposes to reject entirely that contained in the lower part of the butt of the leaf.

B.—The upper portion of the Butt.

Here the arrangement of the tissues correspond for the most part with that at the lower portion of the butt.

The superior or inner epidermis is composed of small cells, with only a very slightly developed cuticular layer. In many specimens no cuticle is visible, the cuticularized outer wall of the epidermal cells being also thin. Higher up in the leaf the cuticle is thick and well developed. It is at this portion of the leaf that the flax gum is mostly developed. At first the gum is a viscid semi-fluid substance, which speedily dries into thin laminæ. This gum is apparently not produced by glands or secreting organs in the tissues of the leaf, but is a superficial formation, produced by degenerative changes occurring in the thick cell-wall and cuticular layer of the epidermis of the upper or inner side of the sheathing portion of the leaf. This accounts for the absence of a thickened cuticle on that part of the leaf, and also for tho absence of all glands or openings on the surface of the leaf by which the gum can be secreted. Gum *tragacanth* is formed in a somewhat similar manner by degeneration of cell-walls; and in sea-weeds, the so-called "intercellular substance" is produced in a similar way. In the spores of *pilularia* and *marsilia*, a gummy secretion is formed at the expense of the cuticular layer. Very little chlorophyll exists in the cells below the upper epidermis at this part of the leaf.

The cellular tissue of the leaf resembles greatly that of the lower butt, but now the fibro-vascular bundles are seen to be more regularly arranged, and the air-cavities or intercellular spaces are much more marked.

The fibro-vascular bundles, near the inner or superior surface, are complete with prosenchymatous wood-cells, spiral vessels, and cambiform cells, the prosenchymatous cells being well developed on both sides of the bundle. Close to the inferior, or outer epidermis, the bundles are not constituted in the same way, in them the prosenchymatous wood-cells largely predominate, and in a few, spiral vessels exist, while in others only wood-cells are visible. These bundles are very regularly arranged, close to the lower epidermis, and only separated from it by two or three small cells. Between these bundles the cells containing chlorophyll are placed, and give a very characteristic appearance to the section.

The large intercellular spaces form a very marked feature in the transverse section of the leaf. They are regularly arranged in a single row in the middle of the leaf, and separate more or less accurately the bundles of the upper side of the leaf from the bundles of the lower. The lower epidermis consists of a layer of small cells, with a well marked cuticular layer. This arrangement holds both for the thick portion of the sheath and the thin lateral parts.

The quantity of fibre in this part of the leaf is greater than that in the lower portion of the butt. Near the lower epidermis the bundles are placed very close together, and form about half of the tissues, while in the rest of the leaf the bundles are few and scattered, and not occupying more than 1-10th of the tissue.

At this portion of the leaf small intercellular cavities, containing a dark reddish-brown fluid, were observed; one situated on each side of the middle line of the sheath, on the superior surface. Similarly coloured marks were also on the leaf, but as their development could not be traced by means of the specimens examined, no opinion can be give respecting them. The irregular arrangement of the cells surrounding them, and their varying depth from the surface is to be noticed. In some places the gum on the surface was deeply coloured of the same tint as the colouring matter contained in these cavities. Careful examination of the development of the leaf would be the only way to make out the true nature of these structures, and to do that would not come within the sphere of a preliminary report like the present.

§ 3.—Structure of the Blade and Tip of the Fresh Leaf.

A.—Lower portion.

As the lower portion of the leaf, or butt, could be more correctly described as the sheath, so the whole upper portion may be described as the blade, or lamina. As we described the lower and upper portion of the butt, or sheath, so we may describe the upper and lower portion of the lamina, the tip or apex, and the blade.

Above the butt, or sheath, the blade appears as a well marked flattened expansion, with a strongly marked keel on the lower side, this keel extending down the butt. No gum is now formed by the upper epidermis, which is glossy and dark green. The margin of the keel and the edge of the leaf is reddish-brown in colour, and differs from the other part of the leaf in appearance.

The arrangement of the different tissues in the leaf differs considerably from that in the sheathing portion. We do not find the fibro-vascular bundles arranged in the same way. The complete bundles, near the inner or superior surface, have disappeared, and we have these bundles placed so as to be in relation to both sides of the leaf, and stretching right across the mesophyll. The small bundles are arranged so as to be close to the inferior epidermis, while a few incomplete bundles are placed close to the upper epidermis. The intercellular spaces, or lacunæ, are largely developed, and divide the large complete bundles one from the other. Cells containing chlorophyll are found on both sides of the leaf, more or less surrounding the intercellular spaces, and placed between the fibro-vascular bundles. These transparent spaces also change in character. Instead of being evident lacunæ they are now composed of numerous cells of large size, with very thin walls, and probably able to carry air in the same manner as the intercellular canals. Another well marked difference in the structure of the leaf is observable, namely, that all the fibro-vascular bundles are partly surrounded by a cellular sheath; a single row of cells, which sharply defines them from the surrounding tissues. This sheath is only very slightly developed in the upper part of the butt, and is altogether wanting in the lower part of the butt. The sheath is, however, not complete, as it is wanting on the side of the bundle next the lower epidermis. Here, as in other parts of the leaf, the fibro-vascular bundles approach very near the epidermis, and are not separated by many cells. It may also be considered as wanting on the other side of the bundles, but the numerous large cells below the epidermis, on the superior side of the leaf, may be looked upon as completing it.

The keel and coloured edge of the leaf is covered by a very thick cuticular layer, this being coloured gives the peculiar appearance to it.

The bundles near the edge become small, and are complete, each bundle being separated from the other by a lacunæ. Near the centre (middle line of the leaf) small bundles are developed between the large ones, but at all parts the same relative position in regard to the upper and lower epidermis is preserved.

B.—Upper portion of Blade or tip of the Leaf.

In the upper part of the leaf the same relations of parts is preserved as in the lower portion of the blade. The bundles, however, diminish very considerably in size, and the quantity of spiral vessels and cambiform cells increases, while the prosenchymetous cells diminish. The bundles, when seen in transverse section, run across the mesophyll, and are placed between the intercellular spaces, several cells separating the bundle from the upper epidermis, while the lower epidermis is in close contact with the bundle. They are also provided with the cellular sheath, like the bundles lower down. The thick coloured cuticle on the keel and margins of the leaf is, in all respects, the same as that described on the blade. The fibro-vascular bundles are best developed on the upper or inner side, few prosenchymatous cells existing on the under side. If the leaf was therefore split at this part, the best fibre would be found on the upper part, and only a small quantity on the under side. Lower down in the leaf this arrangement does not hold, there being as much fibre on one side as on the other; while in some cases more fibres actually exist on the under than on the upper side. The epidermis cuticle cells, containing chlorophyll, &c., resemble those of the other parts of the leaf, and already described.

Large fibro-vascular bundles exist close to the keel and edge of the leaf. These contain much prosenchyma, but are not surrounded by a sheath of cells like the other bundles in the leaf.

§ 4.—Glossy or Superior Surface.

The glossy, or superior surface, is covered with a well developed epidermis. The cells are narrow, and not greatly elongated. A very thick cuticle exists on the free, or outer surface. This cuticle is best developed on the blade, while on the sheath it is very thin when the gum has been formed. The thickened cuticle seems to furnish the material out of which the flax gum is formed. No *stomata* exist in the epidermis of the upper side of the leaf.

§ 5.—Bloom or Inferior Surface.

The epidermal cells on the bloom or inferior surface of the leaf are small, but more elongated than those on the upper surface; the elongation being in the direction of the long axis of the leaf. A well marked alternation of structure of the lower epidermis is seen, an alternation of a band with stomata, and a band without stomata. The band without stomata is found over the prosenchymatous bundles; while the band with stomata exists only over the cells containing chlorophyll. This gives the peculiar banded appearance to the lower surface. The stomata are well developed, and are quadrangular, resembling very much the stomata of the *Agave.* They are very closely packed on the portion of the epidermis on which they exist, while none are to be met with on the epidermis covering the prosenchymatous fibres.

§ 6.—Microscopical Character of Prepared Fibres of Phormium Tenax.

The fibres of the New Zealand flax plant, which are used for manufacturing purposes, consist of the *prosenchymatous wood-cells*, which form part of the fibro-vascular bundles existing in the plant. In this way the New Zealand flax is perfectly distinct in its anatomical and physiological character from Irish flax and Russian hemp. In the plant the prosenchymatous wood-cells exist in bundles, composed entirely of these cells, but much more frequently mixed up with a number of other cells or vessels. The bundles are thus of very different value, some containing much valuable fibre, while others contain comparatively little. When examined with the microscope, the ultimate prosenchymatous wood-cells appear as elongated, more or less cylindrical fibres, tapering towards each end, the tapering ends of the cells over-lapping. The length of these cells is very difficult to determine, and all attempts to isolate a single perfect cell have as yet failed. They must, however, be of considerable length, as several cells have been traced for 2½ inches. The cell, when isolated and viewed from the side, appears as a transparent cylinder, with a cavity. The relative sizes of the cell, and of the cavity, vary very much, and measurements of many fibres are given in this Report. The measurements were obtained by using the *Camera lucida*, and are expressed in fractions of an English inch. The microscope was fixed so that when a power of 500 diameters was used, 1-1000th of an inch in a stage micrometer was magnified to half an inch. Each fibre was carefully drawn, and by means of an ivory rule and compasses the size of both the fibre and cavity could be ascertained with the greatest accuracy. In transverse section the cells appear more or less polygnall, and possess well marked pores or pits on the wall. These pits are very small, and not very numerous,—the pit on one cell always corresponding with another on the next cell. The wood-cells making up the fibres of New Zealand flax are thus porous or pitted cells. The pits are best seen in thin transverse sections of the fibro-vascular bundle, and require a power of 500 diameters for their demonstration.

In structure and general appearance the fibres of New Zealand flax resemble those of Manilla hemp, while they entirely differ from those of Irish flax and Russian hemp. Both Russian hemp and Irish flax consist of *bast-fibres*, the fibre both of Manilla hemp and New Zealand flax being the prosenchymatous *wood-cells* of the fibro-vascular bundles. While these fibres thus differ anatomically and physiologically, they also differ chemically.

If we take six test-tubes, and place in each a portion of one of the fibres, say, carded cotton in No. 1, Irish flax in No. 2, Russian hemp in No. 3, Manilla hemp in No. 4, New Zealand flax in No. 5, and a portion of pine wood in No. 6, then pour a little fuming nitric acid on each, on washing the fibres carefully with water and dilute ammonia we obtain very characteristic results.

No change is produced in the appearance of the carded cotton, the colour and general appearance remaining the same, but by microscopic examination it is found that the fibres have lost their peculiar twist to a considerable extent, and become more cylindrical.

Irish flax—The bast-fibres remain unaltered in colour and general appearance, but under the microscope it was seen that the fibre was very distinctly marked with longitudinal striæ, and the cavity in each fibre was well marked. Here and there portions of wood adhered to the fibres and these became deep brown in color.

Russian hemp remained also unchanged in appearance, the fibres showing well marked longitudinal striæ under the microscope. Portions of wood adhering to the fibres became colored deep brown.

Manilla hemp became at once deeply coloured by the nitric acid, and this colour remained after washing with water and ammonia. When allowed to remain in water for some time it coloured the water yellowish brown. The bundles of fibres were stained, but were little altered in appearance—single fibres, however, becoming more or less twisted.

New Zealand flax, when treated with acid like the others became deep brown, like the Manilla hemp, and when allowed to remain in water tinged it yellowish brown. The sample used had most of the ultimate fibres separate, and the action of the nitric acid was well marked, the fibres becoming twisted and contorted in a very peculiar way.

The pine wood treated with nitric acid gave results similar to those obtained by treating Manilla hemp and New Zealand flax, the wood becoming deep brown, and tinging the water in which it was placed of a yellowish brown hue. The wood cells were also twisted very slightly.

We must therefore conclude that New Zealand flax is much more closely related to Manilla hemp than to Irish flax or Russian hemp; and in this way we need not devote much time to comparing the fibres, either as regards their structure or relations.

A.—Native Samples.

No. 1* of samples of prepared flax may be taken as a good sample. In it the fibres, or wood-cells are united in bundles, but are separable without much difficulty. When examined with the microscope it is found that the cells have a very considerable diameter, varying from ·0006 to ·0008, and that the cavity is small, having only a mean diameter of ·00015. In this sample a single bundle was observed in which the cells were from ·0007 to ·0009 in diameter, the cavity having a mean breadth of ·0004. The ultimate cells were very difficult to separate one from the other, and the bundle appeared dull and wanting in lustre to the naked eye.

The characteristic then of a good native sample of prepared flax is the small size of the cavity compared with the diameter of the fibre. All the strength of the fibre will depend on this, and also it is evident that the thick walled cells can be much more easily detached one from the other than fibres with thin walls.

No. 3† of the samples examined consists of the fibre from the underside of the leaf, which is rejected by the Natives. The fibres vary much in character. Some of the bundles contain very few prosenchymatous wood-cells, and consist chiefly of spiral and porous vessels. Then again, the epidermis adheres closely to the fibro-vascular bundles, and cannot be easily separated, while the cells containing chlorophyll are abundant. In this sample we not only have the bundles dirty from adherent tissue and matter inside the cavity of the fibre, but the bundles are both deficient in prosenchymatous cells, and these, when present, are of inferior quality. They are much more irregular in size, varying from ·00035 to ·0008, while the cavity varies in diameter from ·0001 to ·00035. This size of the cavity shows that the fibre is much weaker, and also that the ultimate cells will be much more difficult to separate one from the other, the thin wall not having strength to withstand the force necessary to separate the bundle into its ultimate cells. If we take the mean measurements of a number of cells of samples Nos. 1 and 2‡ we find that the mean diameter of 17 fibres is ·000655, while the mean diameter of the cavity is ·000154. Taking the diameter of the cavity as 1, the mean diameter of the cavity would be to the diameter of the fibre as 1 to 4·25. If we take No. 3 sample, the mean diameter of 18 fibres is ·000582, while the mean diameter of the cavity is ·000191, the mean diameter of the cavity

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* *Harakeke.*—Common swamp flax from Otaki; stripped and scraped with a shell, then washed for a few minutes in running water. Selected leaves of twelve or eighteen months old.

† From the same plants as Nos. 1 and 2, but stripped from the bloom (or outter) side of the leaf. The tissue obstinately adheres to and discolours these fibres.

‡ Same as No. 1, but not washed.

being to the diameter of the fibre as 1 to 3·04; the fibres being on the average smaller, while the cavity is larger. 88 fibres from the Native samples were measured, and gave a mean diameter of ·000603, and mean diameter of the cavity ·000187, or in the proportion of 1 to 3·22.

B.—Machine-dressed Samples.

In the machine-dressed samples the bundles of fibres had to be more or less broken up, and in this way the samples were irregular, sometimes many of the ultimate fibres being separated, at other times the fibre being closely united in bundles. The characteristic of the machine-dressed sample is the great variation in diameter of the fibres, varying as they do from ·00035 to ·001, while the diameter of the cavity varies from ·000075 to ·000625. In these samples it was very evident that much of the fibre was of inferior quality, that the cavity was so large, and the wall so thin, that the ultimate cells could not be separated, and all attempts to separate them would result in the production of a iarge amount of waste. Taking the mean of 76 fibres from the machine-dressed samples, we get ·000534 as the mean diameter of the fibre, and ·000151 as the mean diameter of the cavity, the cavity thus being to the fibre as 1 to 3·53.

Taking the mean of all the fibres measured (164 in number) we get ·000569 as the mean diameter of the fibre, and ·000169 as the mean diameter of the cavity, or as 1 to 3·36.

§ 7.—Microscopical Character of Prepared Fibres of Manilla Hemp.

Manilla hemp occurs in coarse threads of varying size, which are the fibro-vascular bundles of the plant, removed apparently without any attempt being made to break up the bundles into their ultimate cells or fibres. In appearance the ultimate cells or fibres of Manilla hemp closely resemble those of *Phormium tenax*. They are cylindrical, with a large cavity in the centre. The fibre has, in general, a greater diameter than that of *Phormium*, but the cavity is always much larger. The following measurements show this:—

	Diameter of Fibre.	Diameter of Cavity.
A	·00065	·00025
B	·0007	·00035
C	·0008	·00045
D.	·00125	·0009

They are very variable in size and breadth of cavity, resembling very much a bad sample of *Phormium* fibre. The bundles can only with difficulty be separated into their ultimate fibres or cells, and when doing so for microscopical examination the fibre was nearly always injured, the cavity being easily destroyed.

The Manilla hemp consists of *prosenchymatous wood-cells*, and is, anatomically and physiologically, the same as the fibres of New Zealand flax.

A good deal of cellular tissue adheres to the bundles of fibres, but it is colourless, and there is no trace of epidermis or of cells containing chlorophyll, as in the case of *Phormium* fibres.

§ 8.—Microscopical Character of Prepared Firbes of Irish Flax.

The ultimate bast-fibres of which the flax is composed are not united in large bundles, a few fibres only adhering, and in the specimens examined many of the fibres were quite free one from the other. The fibres appear as a greatly elongated cylinder, with a cavity sometimes well marked, sometimes scarcely visible, at other times wanting. Adhering to the fibres, and often more or less discolouring them, were fragments of tissue, sometimes the epidermis with stomata, from the stem; at other times the cells of the soft-bast or wood-cells from the central portion of the stem. The diameter of the fibre varies from about ·0004 to ·0006.

§ 9.—Microscopical Character of Prepared Fibres of Russian Hemp.

Russian hemp differs entirely in appearance from Manilla hemp and New Zealand flax, but resembles Irish flax very much in its general character. The fibres are more or less separate, some entirely free, others in small bundles. The fibres vary very much in diameter, some being very broad, others narrow, and they appear like longitudinally striated cylinders. Sometimes a cavity exists, at other times none can be traced. The fibres are, on an average, from ·0005 to ·0007 in diameter, and in one fibre in which the diameter was ·0007 the diameter of the cavity was ·0001.

Some cellular tissue was observed adhering to the fibres, but they were cleaner than the fibres of Irish flax. Like Irish flax the hemp consists of bast-fibres, and is, anatomically and physiologically different from the fibres both of Manilla hemp and New Zealand flax.

§ 10.—Nature of the so-called Cement.

The walls of all tissue-cells are constructed on the same type. We have first the primary cell-wall, a thin plate or lamella, composed of cellulose. In thickened cells the thickening material appears as a deposit on each side of the middle lamella, and in general this secondary wall has a different composition from that of the primary cell-wall or middle lamella. In the *Phormium* the primary cell-wall consists of cellulose, which is coloured blue by a solution of iodo-chloride of zinc (Busk's solution), while the secondary wall, making up the great mass of the cell, consists of ligneous matter, and is coloured yellow with Busk's solution. If, therefore, a thin section of the bundle of *Phormium* fibres be treated with Busk's solution, the so-called cement is shown to consist of cellulose, and is coloured blue, while the great mass of the fibre is stained yellow. The cellulose, which forms the primary cell-wall, is that which is soluble in chlorate of potash, and nitric acid (Schultz' process). All the different fibres, Manilla hemp, Russian hemp, and Irish flax, are united in the same way. As this primary cell-wall has small triangular spaces at the places where neighbouring cells meet, and always shows a tendency to split (as in the ripening of fruits in which the cells separate one from the other by splitting of primary cell-wall), little difficulty will exist in separating the fibres one from the other if the walls are strong and thick enough to bear it. The thick-walled fibres used by the Natives, and in which the fibres are separable, demonstrate this fact clearly. As the cells of the *Phormium* differ in no way from all other tissue-cells in the way in which they are united, it is hardly necessary to say more on this point.

N.B.—All measurements in fraction of an English inch.

§ 11.—Measurements of Fibres of Native-dressed Samples of New Zealand Flax.

No. 1.—*Harakeke*, washed.

No. 1*a*. 8 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
A	·0006	·00015
B	·0007	·00015
C	·00065	·000125
D	·00065	·00015
E	·000625	·00015
F	·00075	·00015
G	·0008	·00015
H	·000675	·00025
	Mean ... ·000681	Mean ... ·000159

No. 1*b*. 5 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
I	·0009	·000625
J	·0008	·00045
K	·000825	·0005
L	·000725	·0003
M	·0008	·000325
	Mean ... ·00081	Mean ... ·00044

No. 1*b* was selected from a sample of No. 1. The fibres were closely adherent, and very difficult to separate. In the mass it appeared as a dull white thread wanting lustre. Only one was observed in the sample.

No. 2.—*Harakeke*, unwashed.

9 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
A	·0007	·0002
B	·0007	·0001
C	·00065	·000125
D	·00025	·000175
E	·0008	·00025
F	·000055	·00015
G	·0005	·00015
H	·0006	·0001
I	·0006	·00012
	Mean ... ·00063	Mean ... ·00015

No. 3.—*Harakeke*, back of leaf.

No. 3*a*. 3 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
A	·0005	·000125
B	·00055	·0001
C	·00055	·0001
	Mean ... ·00053	·000108

Best looking samples of No. 3 fibres stained in places.

No. 3*b*. 2 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
D	·00055	·0002
E	·0005	·0001

Fibres very dirty: quantities of cellular tissue adhering to the fibres. The prosenchymatous cells were very few in number (hence small number measured), while the pitted and spiral vessels were very numerous.

No. 3*j*. 9 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
F	·00075	·0002
G	·0004	·0001
H	·00035	·0001
I	·0005	·000125
J	·00045	·0001
K	·0005	·0001
L	·000425	·000075
M	·0005	·00015
N	·000525	·000175
Mean ...	·000488	Mean ... ·000125

Fibres dirty; cellular tissue adhering. The fibres are closely adherent in bundles, which are very difficult to separate into the ultimate cells. The cells are very irregular in size, varying from ·00075 to ·00035 in diameter.

No. 3 8. 9 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
O	·0007	·00025
P	·000725	·0003
Q	·0008	·00035
R	·00065	·0003
S	·0006	·00025
T	·00055	·0002
U	·000575	·000175
V	·0007	·0002
W	·0008	·0003
Mean ...	·00067	Mean ... ·00025

No. 4.—*Harakeke*, soaked and beaten with mallets.

10 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
A	·000575	·0002
B	·00065	·00025
C	·0006	·0002
D	·00055	·000175
E	·0005	·000175
F	·000525	·00015
G	·0007	·0001
H	·00055	·0002
I	·0006	·0002
J	·00055	·000175
Mean ...	·00058	Mean ... ·00018

No. 5.—Swamp flax, only stripped.

No. 5*a*. 5 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
A	·00065	·00025
B	·0006	·000275
C	·000525	·0001
D	·00045	·00015
E	·000575	·000175
Mean ...	·00056	Mean ... ·00019

Fibres dirty; much cellular tissue adherent.

No. 5*b*. 11 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
F	·0006	·00025
G	·0006	·000275
H	·000775	·000175
I	·000475	·00015
J	·000625	·0003
K	·0006	·000275
L	·0007	·0003
M	·0006	·000175
N	·0006	·0002
O	·00055	·0002
P	·000425	·0001
	Mean .... ·000595	Mean ... ·000218

Fibres dirty; much cellular tissue adherent.

No. 6.—Swamp Flax, hackled.

7 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
A	·0008	·00025
B	·00065	·0002
C	·0007	·00015
D	·0006	·0002
E	·000575	·0001
F	·0006	·00015
G	·00065	·0001
	Mean ... ·00065	Mean ... ·00016

No. 7.—Superior quality, specially dressed for spinning.

10 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
A	·0005	·00015
B	·0005	·00015
C	·00055	·0001
D	·0006	·000125
E	·0004	·0001
F	·000375	·000075
G	·00055	·000125
H	·0005	·000175
I	·000475	·0001
J	·000525	·00015
	Mean ... ·00049	Mean ... ·00012

§ 12.—Measurements of Fibres of Machine-dressed Samples of New Zealand Flax.

No. 8.—Passed through two strippers, soaked, sun-dried, scutched, and hackled.

10 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
A	·0004	·00015
B	·000525	·00015
C	·00035	·0001
D	·0004	·000125
E	·0004	·0001
F	·000475	·00015
G	·0005	·0001
H	·0004	·00012
I	·000425	·00012
J	·00045	·00001
	Mean ... ·000437	Mean ... ·000121

No. 9.—Stripped, washed and sun-dried.

9 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
A	·000675	·0002
B	·000475	·0001
C	·000675	·00015
D	·0005	·0001
E	·00045	·00015
F	·000725	·0002
G	·0006	·0002
H	·0006	·000125
I	·00055	·000125
Mean ...	·000583	Mean ... ·00015

No. 10.—Stripped, wet scutched, sun-dried, and scutched.

7 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
A	·00055	·0002
B	·00065	·0003
C	·00055	·0002
D	·00065	·00025
E	·00085	·0004
F	·000775	·0003
G	·00062	·0002
Mean ...	·000663	Mean ... ·000264

No. 11.—Passed through three strippers, washed, and sun-dried.

11 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
A	·0005	·000175
B	·00045	·000125
C	·0004	·0001
D	·00055	·0001
E	·000475	·0001
F	·000675	·000175
G	·0005	·0001
H	·000575	·000125
I	·00055	·0001
J	·000525	·000175
K	·00055	·0001
Mean ...	·000522	Mean ... ·000125

No. 12.—Boiled with alkali, dried, and combed.

10 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
A	·00045	·000175
B	·000625	·0002
C	·000525	·00015
D	·001	·000625
E	·0005	·000175
F	·0006	·000225
G	·0006	·00015
H	·0005	·000175
I	·000525	·0002
J	·000625	·000625
Mean ...	·000595	·00023

No. 13.—Stripped, rolled, and bleached in sulphur fumes.

11 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
A	·00045	·00015
B	·000475	·0001
C	·000375	·000075
D	·0004	·0001
E	·0004	·000075
F	·000425	·00015
G	·0005	·0001
H	·00045	·000125
I	·00045	·0001
J	·000525	·0001
K	·000425	·0001
	Mean ... ·000443	Mean ... ·000106

No. 14.—Steamed, rolled, firmented, and sun-dried.

10 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
A	·0004	·0001
B	00055	·0002
C	·00045	·000125
D	·000424	·0001
E	·0004	·000075
F	·00045	·0001
G	·00041	·000075
H	·0004	·000125
I	·00041	·0001
J	·000475	·00015
	Mean ... ·000437	Mean ... ·000115

No. 15.—Machine scraped, washed, and sundried.

8 Fibres examined.

	Diameter of Fibre.	Diameter of Cavity.
A	·000725	·000175
B	·000525	·000125
C	·00075	·000125
D	·000675	·000125
E	·00065	·00015
F	·000625	·00015
G	·00085	·00015
H	·0006	·0001
	Mean ... ·000675	Mean ... ·000137

B.—Chemistry of Phormium Tenax.

Report by Arthur Herbert Church, M.A., Oxon, Fellow of the Chemical Society of London, and Professor of Chemistry in the Royal Agricultural College at Cirencester, England.—July, 1871.

Contents.

§ 1.—General Conclusions.

From the results of the Chemical studies which I have made of the *Phormium tenax*, I conclude—

1. That the best and strongest prepared *Phormium* fibres are those which, while fulfilling the requisite physical conditions and the microscopic conditions determined by Dr. M'Nab, contain the smallest quantity of mineral matter and the largest quantity of hygroscopic water.
2. That the age or stage of development of the fibre has much to do with its chemical deportment, and with its strength; and that a considerable portion of the fibre in the leaf must be condemned, both on miscroscopical and chemical grounds, as of very small value.
3. That *Phormium* fibres are more easily and more considerably affected by chemical reagents and by water at the boiling point, and at higher temperatures, than most other fibres used for fabrics, ropes, &c.
4. That *Phormium* fibres are very readily wetted by water and by sea-water, and that this wetting takes place to a small extent even after the fibres have absorbed a considerable amount of wood tar. The misroscopic structure of the fibre serves to explain this observation.
5. That the fact stated in (4) above, taken in connection with the observation that *Phormium* fibres contain much matter soluble in water or liable to change, helps to account for the decay of ropes made with this material.
6. That the use of a mixture of lubricating, or machinery paraffine oil with wood tar seems to prevent the entrance of sea water and the proneness to change in *Phormium* fibre. It is also suggested that as the conversion of *Phormium* fibres into *papyrine*, by a brief immersion in sulphuric acid, of the strength used in the manufacture of vegetable parchment, seems to toughen, strengthen, and waterproof them; this process might be made use of to improve inferior samples of fibre.
7. That the ultimate fibres are not held together by any cement, but by their cell-walls. These, however, being easily affected by various agencies, are, together with other changeable constituents of the material, a cause of disintegration and weakness.
8. That the treatment of the plant of *Phormium*, or of its fibre with alkaline matters, especially at a high temperature, may, by removing the oil, tend to cause the harshness shown by some fibres and otherwise injure them.
9. That the use of the softest water, of a well regulated temperature, and of effective yet uniformly exerted mechanical power, seems to be of importance in the preparation of *Phormium* fibre.

The relative value of different processes of treatment and bleaching did not come within the scope of the present preliminary inquiry, but could be ascertained with much greater ease than before, through the data given in the present report.

Analysis of Fibre of Phormium Tenax.

§ 2. Series I.—Determinations of moisture or Hygroscopic water in certain samples of prepared Fibre described in Progress Report, page 20, (App. I., p. 3).

Native Dressed.

	Per centage of water.
No. 1. *Harakeke*, selected 12 to 18 months old, stripped, scraped, and washed	12·76
No. 2. The same, but not washed	11·87
No. 3. From same plants as 1 and 2, but from the opposite side of leaf ...	11·15
No. 5. Common swamp flax from Otaki, stripped, but not washed or scraped	10·77
No. 6. Same as No. 5, but hand hackled	11·05
No. 7. From the Waikato, Native dressed	11·52

Machine Dressed.

No. 8. Mr. Stonyer, Kaiapoi	12·49
No. 9. Captain F. W. Hutton, Waikato	11·31
No. 10. T. S. Macffarlane, Auckland	11·81
No. 11. G. Booth, Waikoura Mills	11·81
No. 12. Riky's process	11·91
No. 13. M'Farlane & Wilson, Whakatane	11·61
No. 14. John Journeaux, Wellington	10·77

Series II.—Determinations of water or Hygroscopic moisture in other vegetable fibres for comparison.

	Per centage of water.
Manilla Hemp	13·22
Russian Hemp	10·47
Irish Flax	10·76
Carded Cotton	6·90 7·56
Flax fibre in the form of Swedish filtering paper...	9·54 8·40 8·60

§ 3. Series III.—Determinations of Ash or Mineral Matter in certain samples of prepared Fibre. (Same specimens as in series I, pages 5 and 6).

	Per centage of ash.
No. 1	·50
No. 2	·93
No. 3	1·50
No. 5	1·61
No. 6	1·23
No. 7	·73
No. 8	·44
No. 9	·59
No. 10	·53
No. 11	1·09
No. 12	·71
No. 13	·63
No. 14	1·08

Series IV.—Determination of Ash or Mineral Matters in other Vegetable Fibres for comparison.

	Per centage of ash.
Manilla Hemp	2·02
Russian Hemp	1·44
Irish Flax	1·23
Carded Cotton	·11
Swedish Filtering Paper	·46

Summary of the Four preceding Series of Experiments.

Phormium tenax.	Per centages in various fibres of Water.	Ash.
No. 1	12·76	·50
No. 2	11·87	·93
No. 3	11·15	1·50
No. 5	10·77	1·61
No. 6	11·05	1·23
No. 7	11·52	·73
No. 8	12·49	·44
No. 9	11·31	·59
No. 10	11·81	·53
No. 11	11·81	1·09
No. 12	11·91	·71
No. 13	11.61	·63
No. 14	10·77	1·08
Manilla Hemp	13·22	2·02
Russian Hemp	10·47	1·44
Irish Flax	10·76	1·23
Carded Cotton	7·23	·11
Swedish Filtering Paper	8·85	·46

§ 4.—Cellulose in Phormium Fibre.

The term "cellulose" is used in chemical and botanical literature without much precision. The whole question of the real nature of the substances named "cellulose," "bast," and "fibre," requires a thorough investigation. In the following experiments I have aimed at comparative rather than absolute results; but, at the same time, I have not rested content with the indications furnished by the usual method of determining the per centage of fibre in vegetable products. A control of the results has been attempted by means of the employment of three different processes. As these methods will be frequently alluded to subsequently it may be as well to describe them briefly here.

I.—*The Nitric Acid and Potassium Chlorate process, or F. Schultze's process.*

Two grams* of the dry substance are placed in a glass stoppered bottle with 1.6 gram potassium chlorate, and 24 grains nitric acid of spec. grav. 1·10. The mixture is left for fourteen days at a temperature not exceeding 18° centrigrade. At the expiration of this time, the contents of the bottle are mixed with some water, brought upon a filter and washed, firstly with cold and secondly with hot water. When this washing is complete, the fibre is emptied into a heater and heated to 74° C for about 45 minutes with weak ammonia solution, (1 volume commercial ammonia to 50 volumes of water). The fibre is then brought upon a weighed filter; and washed, firstly with dilute ammonia, as long as this passes off colored, then with cold and hot water, then with alcohol, and lastly with ether. Carded cotton gave by this method 91·15 per cent of residue. Carded cotton may be regarded as one of our purest forms of normal cellulose, as may be seen by the following analysis:—

	Per cent.
Hygroscopic water	7·56
Cellulose	91·15
Oil	·51
Ash	·11
Albuminoids and undetermined	·67
	100·00

II.—*The Acid and Alkali method.*

Three grams of the powdered or finely cut sample are placed in a large beaker, 150 cubic centrimeters of water added, and the mixture brought to the boiling point, with constant stirring to avoid burning, 50 centrimeters of five per cent H2 SO4 are then added, and the boiling continued for half an hour; the normal total volume of 200 cubic centrimeters being obtained throughout the operation by the addition of a little boiling water. Collect on a filter the residue from the digestion with acid, after having siphoned off the clear supernatant liquid. The residue is to be thoroughly washed on the filter with hot water, and then syringed off the paper into the beaker with about 100 cubic centrimeters of hot water. Fifty cubic centrimeters of a five per cent solution of Na HO are next added, and the beaker filled up with hot water to the mark indicating 200 cubic centrimeters. The mixture is boiled for half an hour, some cold water added, and the whole allowed to rest. When the supernatant liquid is clear it is siphoned off, and the residue collected on a weighed filter, washed with the dilute ammonia water used in method I. as above; and in the remaining steps of the process treated exactly as described in detailing that method.

III.—*The Sulphuric Acid method.*

One gram of the substance is placed in a small stoppered bottle with 30 cubic centrimeters of sulphuric acid of specific gravity 1·53, and allowed to rest 36 hours. The mixture is then washed into a beaker, diluted with water, filtered, and the residue on the filter washed with warm water. The rest of the process is conducted as in methods I. and II. This method removes from mixed fibres all the normal cellulose they contain, dissolving, for instance, *cotton* completely, and *linen* nearly so, but removing smaller quantities of substance from wood tissue.

Cellulose.—Determinations of the per centage of Cellulose in various specimens of prepared *Phormium tenax* fibre, and in other fibres, for comparison.

	By Method 1. per centage.	By Method II. per centage.	By Method III. per centage.
Phormium fibre No. 1	73·1	...	...
" " No. 5	67·5	...	...
" " No. 9	69·0	...	...
" " No. 11	72·0	49·76	7·1
Manilla Hemp	68·80	...	...
Irish Flax	74·10	...	...
Russian Hemp	72·10	...	...

At a slightly higher temperature Method No. I. gave rather smaller per centage of residual cellulose. In these cases, which are given below, the residues were treated successively by Methods II. and III., and thus the cellulose, and incrusting or deposited matters, were separated into three kinds:—

	Cellulose by Method I. Per centage.	Cellulose by Method II. Per centage.	Cellulose (?) by Method III. Per centage.
Phormium fibre No. 1	64·25	52·22	·48
" " No. 13	63·00	46·45	·70

* The gramme of 15·432 grains is here meant, and also throughout the Report.

It will here be seen that the cellulose and fibre were divisible into three parts, by a successive treatment by Schultze's process, (I); by the acid and alkali process, (II); and by the H_2SO_4 or sulphuric acid process, (III). The results may be thus rendered:—

		Per cent.	
Phormium fibre, No. 1.	Crude Cellulose=	64·25	
	Made up of	12·03	insoluble by I. soluble by II.
		51·74	insoluble by II. soluble by III.
		·48	insoluble by I., II. and III.
Phormium fibre, No. 13.	Crude Cellulose=	63·00	
	Made up of	16·55	insoluble by I soluble. by II.
		45·75	insoluble by II. soluble by III.
		·70	insoluble by I., II. and III.

§ 5.—Action of Water at various temperatures uppon the Fibre of Phormium tenax, &c.

1. Clean Flax fibre (linen), in the form of Swedish filtering paper, was first tried.

Boiled with distilled water for twelve hours it gave up to the water about one per cent of organic matter, and about three quarters of a per cent of mineral matters, chiefly silica. The numbers were as follows:—

	Grams.
Swedish filter employed weight	·55
Weight of dry substance extracted	·0095
Of which the Ash amounted to	·0040
And the organic matter dissolved	·0055

The water did not become acid in this experiment.

II.—A similar filter to that used in experiment I, was digested with water in a sealed tube at a temperature fifty degrees above boiling water, namely at 150° Centigrade. The digestion was continued four hours. The water became of a straw yellow colour, but remained neutral to test paper.

	Gram.
Sweedish filter employed	·55
Weight of red-brown extract dissolved by water	·016
Weight of ash in this residue	·0055
And the organic matter dissolved	·0105

III.—When ·5 gram of *Phormium* fibre (No. 1) was boiled twelve hours with distilled water, the liquid remained neutral to test paper; on evaporating to a small bulk the residual solution did show a faint acid reaction. The dry matter in this solution corresponded to 3·6 per cent. of the fibre taken.

IV.—When ·5 gram of *Phormium* fibre No. 2 was digested with distilled water, in a sealed tube, at 150° C. for four hours the water became turbid and of a distinct acid reaction, with smell of burnt sugar. On washing the fibre with water, a pink colouring matter was developed. The amount of substance removed from the fibre at 150° C. by water, amounted to 19 per cent. of the original weight taken. It was a brown soluble substance, which gave a ready precipitate of red copper suboxide when boiled with Fehling's test for sugar. This result may have been due, however, to the presence not of any kind of sugar but of "pyrocatechin," or some allied product. The solution was sweet, with a bitter aftertaste.

V.—Manilla hemp, similarly treated, gave similar products, amounting to 15·4 per cent.

VI.—Irish flax, similarly treated, gave similar products, amounting to 10·4 per cent.

VII.—St. Petersburgh hemp, similarly treated, gave similar products, amounting to 10·0 per cent.

Table containing Summary of Results obtained in Experiments on the Action of Water upon Phormium Tenax and other Fibres.

——	Per centage of organic matter dissolved out of the fibres by water, at the temperature of	
	100° C.	150° C.
Linen filter paper	1·0 per cent.	1·9 per cent.
Phormium tenax, Sample No. 1	3·6 "	...
" " " No. 2	...	19·0 "
" " " No. 13	...	24·4 "

From the foregoing results, it will be seen that prepared and cleansed New Zealand flax fibre is acted upon by boiling water to more than three times the extent to which flax from *Linum usitalissumun* is affected by the same treatment. And at the higher temperature, from one-fifth to one-fourth of the whole *Phormium* fibre is dissolved by water, while the true flax fibre does not lose more than two per cent. of its weight under the same circumstances.

These facts point to an inherent difference in the quality of the organic substances, making up the material of the *Linum* and *Phormium* fibres.

Manilla hemp was similarly affected, as in the case of *Phormium* fibre, 15·4 per cent. of organic matter being removed from it by water, at 150° C.

Under the same circumstances, Irish flax lost 10·4 per cent. of organic matter, and Russian hemp 10 per cent.

§ 6.—Nitrogenous Matters, or "Albuminoids" in the Prepared Fibre of Phormium Tenax.

It was found by a careful analysis of No. 11 specimen of New Zealand flax that it contained ·267 per cent. of nitrogen. This corresponds to a per centage of albuminoids, amounting to 1·69 per cent.

In the perfectly dry flax (No. 11), the amount of nitrogen is ·301 per cent., and the amount of albuminoids is 1·91 per cent.

This proportion is greater than that found in many other prepared fibres. Careful analyses of cotton (carded) and linen (Sweedish filter paper) gave the following results, which are here put down by the side of those just recorded:—

——	*Phormium.*	Cotton.	Linen.
Per centage of Nitrogen	·267	·079	·087
Per centage of Albuminoids	1·69	·50	·55

§ 7.—Oil or Fat in the Prepared Fibre of Phormium Tenax.

The presence of an oily matter of some sort in the cleansed and prepared fibres employed in the manufacture of textile fabrics is not generally recognised. This oily matter, as it occurs in the dressed fibre of *Phormium tenax* and in Manilla hemp, is, in great part, volatile at the temperature of boiling water.

With the sample of *Phormium* fibre, No. 10, the following results were obtained:—

Per centage of oil, dried at 100° C. (212° Fahr.)	·25
" " " " " "in vacuo" ...	1·08
In Manilla hemp—	
Per centage of oil, dried at 100° C. (212° Fahr.)	·11
" " " " " "in vacuo" ...	·48
In carded cotton—	
Per centage of oil fixed at 100° C.	·51

Vegetable fibres of all kinds, from which the natural oil has been removed by heat, alkalies, or solvents, are harsh and dry to the touch, and easily and rapidly wetted by water.

§ 8.—Absorption of Sea Water by Phormium Fibre.

In the experiments made on this subject, it seemed that the *Phormium* fibres were more quickly and thoroughly wetted by sea water than were those of Manilla. More action on the fibres also occurred in the case of the *Phormium.* The extent of the absorption was measured by immersing the soaked fibres in a solution of nitrate of silver, and then exposing them to sunlight.

It may be mentioned, in this connection, that *Phormium* fibres, which had been carefully dressed with Stockholm tar, were still capable of taking up a small quantity of sea water.

§ 9.—Absorption of Wood-tar by Phormium Fibre.

No difficulty whatever was found in causing prepared fibres of *Phormium* to take up as much tar as those of Manilla. When a small quantity of paraffine, machinery, or lubricating oil was mixed with the tar, several advantages seemed to accrue. This oil, which is the last product of the distillation of petroleum, &c., imparts flexibility to the fibre, gives it greater tenacity, and, by its remarkable diffusive power, serves to keep out sea-water and other aqueous liquids. Being itself unalterable and unoxidizable, this oil has no tendency to promote chemical changes in the fibre which has been dressed with it. As, however, it does not dry, it cannot be used alone.

§ 10.—The foregoing analyses enable me to present a tolerably complete idea of the constituents which go to make up 100 parts of one of the samples (No. 13) of dressed New Zealand flax fibre.

Analysis.

Water	11·61
Ash	·63
Cellulose, A.	16·55
Cellulose, B.	45·75
Cellulose, C.	·70
Oil, partly volatile	1·08
Albuminoids	1·69
Gum and matters, soluble in water at 150° C.	21·99
	100·00

The oil and albuminoids in the above analysis are transferred from the analysis of similar fibres, Nos. 10 and 11 respectively.

§ 11.—Analysis of the Fresh Plant of Phormium Tenax.

The plant operated upon was received from the Royal Gardens at Kew, in May. One half of two leaves (65 and 68 inches in length respectively) was operated upon, being carefully cut up, mixed and sampled for the experiments now to be related.

The plant analysed contained:—

71·95	per cent. of water.
28·05	„ dry matter.
100·00	

This dry matter contained in 100 parts—

Fixed oil and fat (soluble in ether)	2·55
Resin and chlorophyll (soluble in alcohol)	3·24
Gum and matters (soluble in cold water)	17·29
Starch and matters (soluble in hot water)	4·28
Albuminoids	5·05
Ash, or mineral matters	5·56
Cellulose and fibre, by process I. (See § 4)	44·47
Other substances not specially determined	18·56
	100·00

These results are not given as by any means complete, though it is hoped that they will serve to indicate the proper direction for further inquiry into the best treatment for the preparation of the fibre from the plant. To this point another series of experiments tended; in these the nature of the 44·47 per cent. of cellulose, above given, was tested. It was found that it lost 8·71 parts by treatment with acid and alkali in process II., leaving 35·76 per cent. This residue, treated by process III, left a final residue amounting to 11·37 per cent. of the dry plant. Comparing this result with that obtained in the similar treatment of the prepared fibre (See § 10) it is clear that much hard and corky substance in the original plant is rejected in the processes of manufacture.

The analysis of the *fresh* plant will be represented by the following numbers:—

	Per cent.
Water	71·95
Fixed oil or fat	·72
Resin and chlorophyll	·91
Gum and matters (soluble in cold water)	4·97
Starch and matters (soluble in hot water)	1·20
Albuminoids	1·51
Ash or mineral matters...	1·59
Cellulose and fibre, by method I.	12·47
Undetermined	4·68
	100·00

In considering the nature and proportion of the various ingredients of the *Phormium* leaf enumerated above it must not be forgotten that nearly all of them are present, to some extent, in the best prepared fibre derived from this plant. This matter has been already discussed in §§ 2 to 7, and in § 10.

(No. 180.)—J. S. Ricketts, H.B.M. Consul, Manila, to His Excellency Sir G. F. Bowen, G.C.M.G.—20th July, 1871.

Sir,—

In accordance with the instructions communicated to be by the Earl of Granville, I have the honor to transmit to you, herewith enclosed, a copy of a despatch addressed by me to H.M.'s Foreign Office on the culture and preparation of Manila hemp.

I have, &c.,
J. S. Ricketts.

My Lord,— Manila, 20th July, 1871.

I have the honor to acknowledge the receipt of a despatch of the 17th of March last, No. 2, signed by Mr. Odo Russell, transmitting to me a copy of a despatch from His Excellency the Governor of New Zealand, requesting information on the culture and preparation of Manila hemp.

There is no official publication to be found imparting any information on this subject.

The following information will, however, I trust enable the Flax Commission to form some idea of the properties of the Manila hemp, its method of preparation, and its value.

Culture.

The Manila hemp is made from a fibre of a species of musa called *Musa Troglodytarium Textoria.* It gives a large quantity of seed, and its leaves are more pointed and of a somewhat darker color than the common Plaintain tree. It is mostly propagated by transplanting its offshoots, which are numerous.

In some places the fruit of this tree is bitter and not edible, in other places it is eaten by the natives; there would, therefore, appear to be more than one sort of musa from which the hemp is collected. It is generally speaking planted on the slopes of hills, and requires some little shade and plenty of moisture.

The trees are planted from six to eight feet apart, the earth being well heaped up on the roots. At the end of the third year, previously to bearing fruit, the hemp tree is cut down and the fibre extracted.

A full sized tree gives, I am told, from one to one and a-half pounds of hemp. Too rich a soil is not good for this plant, and tends to the growth of the leaf and the diminution of the fibre.

This "musa" is found in nearly all of these islands, and I have seen it growing wild in many places in the interior: it is also to be found in Java and Borneo.

Process of Manufacture.

Numerous inventions have been made for the purpose of working up this fibre, but none of them appear as yet to have met with any success: indeed the hemp still continues to be produced by manual labour.

Immediately the tree is cut down it is stripped of its linings; these are then cut into pieces three or four inches wide: on this they are drawn underneath an instrument resembling a saw fixed in a block of wood. The fleshy part of the cortex is thus scraped off and the fibre alone remains; this is then placed in the sun to dry.

Two persons, one engaged in cutting down the trees and stripping them, and the other in extracting the fibre, can work up some 25 pounds of clean hemp in the course of one day.

In some places the hemp is cultivated on the *Metayer* system, the workmen receiving one half the quantity produced; in others, and indeed generally speaking, it is brought to market by peasant proprietors.

Supposing the two persons are able to produce 25lbs of clean hemp per diem, we have, if they labour 24 days in the month, (and the natives seldom work more than this), 600lbs or about 4½ piculs* as the produce of their labour during that time. The land in most places being but of a nominal value, the actual cost of production would be little more than the value of the labour. Now, taking this at $5 a head per month, the cost of production would seem to be about $2 22 cents. the picul.

Money wages are never paid in the hemp districts; the labourer generally receives half of the hemp produced by him.

The cost of maintaining a Native may, including taxes, be calculated at about $5 a month as above mentioned.

Prices of Hemp.

When at Manila the market price of hemp is $8 the picul, at the port of shipment in the hemp district it is about $6½; and if some distance in the interior, $4 or $5. In the year 1861, the price of hemp in Manila was as low as $2 73 cents per picul; the Natives at that time could not have obtained more than $1 87 cents.

Hemp now sells at Manila at $9 per picul, and during the last year its average price was $10. The Natives here labour to obtain the mere necessaries of life, with which they are content; having obtained these, they manifest no regard for the future, and express no desire to accumulate. Hence, high prices do not, as in other countries, call forth an additional supply.

Should any machinery be able to be invented capable of supplying the place of manual labour in the extraction of this filament, the exportation of the same from these Islands would soon receive a considerable increase, for it must be borne in mind that the limited quantity of hemp produced is due solely to a scarcity of the labour necessary for the process of its manufacture, and not to any scarcity of the plant.

It is worthy of observation that the centre of this musa yields a very fine fibre, which is used for the manufacture of a texture, much valued by the Natives, and called "Sinamay." The fibre takes also a blue and red dye, the latter is obtained from the use of the leaves of a plant called "Payonguit" and the former by the application of the root of the *Morinda* mixed with a little lime.

I have, &c.,

J. S. Ricketts.

The Right Hon. the Earl of Granville, K.G.,
Her Majesty's Secretary of State for Foreign Affairs, &c., &c., &c.

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* A picul is equal to 133⅓lbs. avoirdupois.