REPORT

ON

INDIAN FIBRES

AND

FIBROUS SUBSTANCES

REPORT

ON

INDIAN FIBRES AND FIBROU SUBSTANCES.

REPORT

ON

INDIAN FIBRES AND FIBROUS SUBSTANCES

EXHIBITED AT THE

Colonial and Indian Exhibition, 1886,

BY C. F. CROSS, E. J. BEVAN, AND C. M. KING,

IN ASSOCIATION WITH

E. JOYNSON, ESQ.

WITH

NOTES OF METHODS OF TREATMENT AND USES PREVALENT IN INDIA,

BY DR. GEORGE WATT, C.I.E., M.B., C.M.,

Published by Authority of the Secretary of State for India.

E. & F. N. SPON, 125, STRAND, LONDON.
NEW YORK: 35, MURRAY STREET.
1887.

PREFACE.

THIS report deals chiefly with the results of a laboratory investigation of the vegetable fibres exhibited in the Indian Section of the recent Colonial and Indian Exhibition. In order to explain the circumstances under which the work was undertaken we cannot do better than quote from the official minutes of the Conference at which the matter was decided. The following is an extract from the Report of a Conference held in the commercial room of the Imperial Indian Court of the Colonial and Indian Exhibition, 16th June, 1886.

"Sir E. C. Buck believed that the Government would be prepared to furnish any samples that might be required for the purpose of chemical examination and procure most of the information likely to be called for. He could not undertake to say that the funds would be forthcoming for scientific examination.

"Mr. Cross (of Messrs. Cross and Bevan) with Mr. Joynson, then made a liberal offer to make scientific and practical experiments on the whole series of fibres in the Indian Courts, and promised to send an official letter the following day to that effect. All that these two gentlemen asked for was, that the results of their investigations might be published by the Government of India, and that samples in reasonable bulk should be supplied, accompanied with any information which might be obtained as to the available quantity and probable price."

Perhaps the utmost that we can hope to do in publishing the results of this investigation is to indicate the scope of a more adequate treatment of the subject. So long as the conduct of such work is left to the enterprise of private individuals, progress, in so vast a field of inquiry, must necessarily be slow. When the vegetable fibres come to be recognised as constituting a special field for research, and worthy the attention of those who have command of the necessary resources, we venture to predict a considerable gain to science in the results of the systematic and sustained investigations which would follow.

CONTENTS.

PART I.

To those who are familiar with the subject of vegetable fibres, with the extensive literature of the natural history of fibre-yielding plants and of the technology of the fibres which they yield, it may seem at first sight presumptuous to express the opinion that our knowledge rests upon insufficient foundations. With those engaged in research in this department, on the other hand, the opinion soon becomes conviction: the subject calls for reinvestigation. The exceptional opportunity afforded by the exhibit of fibres in the Indian Court of the Colonial and Indian Exhibition—so extensive a collection of well authenticated specimens—could scarcely fail to attract the authors of this report, who have been now for some years engaged in the investigation of vegetable fibrous substances. The opportunity appeared to offer itself, *first*, of testing, by a wider range of applications than had hitherto been possible, the method adopted in the examination of these substances, which had been built up by selection from those of previous investigators, as well as from the results of original work; and *secondly*, presuming the method to be satisfactory, of classifying the various fibres according to the results—the classification being itself a test of the method—and so reduce to a preliminary order what has certainly proved a somewhat refractory group of natural phenomena. This, our primary object, was the purely scientific; side by side was the collateral and, in its way, equally interesting search for "practical" results. On this side of the question nothing strikes one so much as the smallness of the number of the many available fibres which are actually employed in European manufactures; this restricted application of raw materials, virtually unlimited in number and variety, introduces a very important issue, a further direction of inquiry, into its causes; whether they lie in the properties of the fibres themselves, or rather in the incidents of distribution and commerce; and whether, therefore, we are to endorse the present exclusion of the greater number of available fibres, or can show cause for their more extended application. We are aware that we are not the first to enter upon such an inquiry, and we would more particularly instance amongst those who have preceded us, Dr. Hugo Müller, whose treatise on the vegetable fibres, published in the Vienna Exhibition reports (1873), is a valuable contribution to the chemistry of the subject, to which we ourselves are not a little indebted; and the late M. Vétillart, whose '*Études sur les fibres végétales textiles*' * is of especial importance in elucidating the minute structure of these substances, and in correlating structural features with practical applications. These authors have kept in the main to a distinct line of investigation, chemical *or* microscopical, only incidentally introducing the other, its essential complement. A method compounded of the two lines of inquiry must necessarily give a more complete account of the subject-matter, and this we think will be found to result from the method about to be described. At the same time we do not desire in any way to contrast it with the foregoing, of which it is the natural outcome and development.

We think it necessary to enter into a somewhat detailed description, considering the establishment of a standard method to be of first importance. Systematic inquiry, based upon uniform method, must contribute more than anything to the scientific development of the subject, and consequently to sound practical results.

It will not be necessary to treat at any length the chemistry of the fibre substances, but for the better explanation of the analytical method, it will be well to recall briefly the main outlines of the subject. The prototype of the celluloses is the cotton fibre in its bleached state. The bleaching process consists in a treatment with boiling alkaline solutions (hydrolysis), followed by immersion in a bleaching solution, the whitening action of which is due to an oxidation of the discolouring substances and their conversion into colourless derivatives, which are dissolved by the solution. This residue is pure cellulose; and generally, every fibrous substance submitted to a similar treatment, or succession of treatments, yields a similar residue. While these more resistant residues or derivatives have sufficient resemblance to one another and to the prototype to entitle them to description under this same term cellulose, a closer investigation shows them to be differentiated in various ways, chemical as well as structural. Into these distinctions we do not here propose to enter further than to point out that the term cellulose does not designate a chemical individual, any more than sugar or alcohol, but is a group name, and is applicable in this case to an empirical aggregate obtained as already indicated.

* Paris, 1876.

The non-cellulose constituents of the several fibres are, on the other hand, so entirely distinct, that a chemical classification, according to the characteristics which they impart to the fibre substance, is possible. There are three well-marked divisions in this classification. Viewing the fibre substance rather as a compound, than a mixture of the cellulose and non-cellulose—without entering into the evidence upon which this view is based—the three groups of compound celluloses are the pecto-celluloses, ligno-celluloses, and adipo-celluloses. Of these, the latter has only an incidental connection with our subject, its distribution being confined to the cuticular and protective tissues of plants, which are never fibrous, but cellular. The pecto-celluloses are easily resolved by boiling with dilute alkaline solutions, the non-cellulose being converted into hydrated pectic derivatives: hence the term. Chlorine, in presence of water, does not combine with the fibre substance, but oxidises and bleaches. The ligno-celluloses are slowly hydrated and partially dissolved by boiling alkaline solutions, but not resolved except at very high temperatures. Moist chlorine attacks these compounds in an altogether different way, entering into combination and forming yellow or orange-coloured derivatives which have been shown to be related to the trihydric phenols. Most characteristic is the reaction of these chlorinated compounds with sodium sulphite, being dissolved by solutions of this salt with formation of a brilliant magenta colouring matter. The ligno-celluloses have a number of other well-known and distinguishing colour reactions. By treatment with a mixture of concentrated nitric and sulphuric acids they are converted into bright yellow derivatives, which may be described as ethereal nitrates, allied to the pyroxylins. The ligno-celluloses are further distinguished from the preceding group by higher carbon percentage (46–49), exceeding that of ordinary (cotton) cellulose (44·4) by as much as the pecto-celluloses contain less (40–42). The adipo-celluloses, as the term indicates, are distinguished by the fatty nature of the non-cellulose constituent, which, in fact, conditions their protective action. The non-cellulose is not a fat or wax in respect of such physical properties as fusibility and solubility in the ordinary solvents of these bodies, though there is a resemblance in touch, and in the power of these compound celluloses of resisting water: it is rather in the products of their various decompositions that the similarity of constitution is traced. By boiling dilute nitric acid, for instance, they are resolved into cellulose, and products of oxidation, such as adipic and suberic acid, &c., similar to those obtained from the fats by similar treatment. This group of compound celluloses is further distinguished by high carbon percentage (65–75), and by being with difficulty attacked by hydrolytic agents. As before stated, however, this latter group does not come to be considered in the analytical method as applied to the isolated fibres: in the processes of isolation, however, from the plant, the separation of the fibres from such cuticular tissues is usually an important element, and will therefore require to be noticed.

We may now describe the method of chemically investigating the fibres, and take the opportunity, in giving the rationale of each process, of further elucidating general principles.

Moisture.—All the celluloses hold, in their ordinary state, a certain proportion of moisture, or as we may term it, water of condition, which within the limits of variation (1–2 per cent.) due to atmospheric changes, is definite, and characteristic of each fibre. It is noteworthy that the proportion of hygroscopic moisture is an index of susceptibility of attack by hydrolytic agents: it is certainly true that the textile fibres of the highest class are distinguished by their relatively low moisture. The extent to which this condition is applicable will be seen by an examination of the table of analytical results.

It is scarcely necessary to say that the moisture is determined by drying a weighed quantity of the fibre. It is necessary to raise the temperature to 110° to drive off the whole of the water: at 100° a fibre will often retain 1 per cent. of its weight. Owing to the variations in this constituent, it is expedient to express all the results of analysis as percentages of the dry fibre.

Mineral Constituents.—The ash left on incinerating the fibre is determined in the usual way. The proportion is low in the ligno-celluloses, higher in the pecto-celluloses, and especially when the proportion of non-cellulose is high. Cellular tissue further contains a higher proportion of mineral constituents than the fibres, and an admixture of the former, therefore, raises the percentage.

Hydrolysis.—There are two classes of reagents which intensify that resolving action of water upon organic bodies, known as hydrolysis; they are the acids and alkalis. Of these, the former, for the most part, exert a very destructive action upon the vegetable fibres, and though the study of this action would, doubtless, afford valuable information, it has not been found expedient to include it in our scheme of analysis. The action of boiling dilute alkalis, on the other hand, effecting a simpler resolution, and involving very important points in the practical applications of the fibres, gives results which form a necessary part in their diagnosis. A convenient, though of course arbitrary method, has been selected, as follows: the fibre is boiled (*a*) for five minutes in a solution of caustic soda, 1 per cent. Na_2O, washed, dried, and weighed. The loss of weight presents the proportion of the fibre which yields to the solvent action of the alkali; (*b*) in a second portion the boiling is continued for one hour. The loss of weight is an indication of the "degrading" action of the alkali. In many of the pecto-celluloses the hydrolytic action of the prolonged boiling is such that the non-cellulose is almost completely dissolved away; generally, in this class, the loss is considerable, and the difference between the loss in (*a*) and (*b*) also. Further, the hydrolytic effect is extended to the undissolved portion or cellulose, and the evidence of the hydrating and gelatinising action is the stiffening of the fibres on drying, and when the action is very pronounced, re-agglutination into bundles which dry to wiry strands. This latter effect is minimised by dehydrating the boiled specimen with alcohol, and drying at a gentle heat. The hydrocelluloses, as already stated, are not so readily attacked by the dilute alkalis, and it is only when digested at very high temperatures that the resolution into cellulose and non-cellulose is effected. In either group, it will be found that whatever the condition of the hydrolysis it is always more or less incomplete, and requires, for the isolation of the cellulose, to be supplemented by the treatment about to be described.

Cellulose.—A fresh specimen, having been boiled in the dilute alkali (1 per cent. Na_2O), is well washed and exposed for one hour, at the ordinary temperature, to an atmosphere of chlorine gas. It is then removed, washed, and treated with a solution of sodium sulphite, which is slowly raised to the boil. After two or three minutes' boiling, it is washed, on a filter when necessary, though in most cases it may be so placed in a funnel as to act as its own filter; lastly, treated with dilute acetic acid, washed, dried, and weighed. The percentage yield on the raw fibre is the most important criterion of its composition and value. We have already pointed out that these celluloses, although similar in external characteristics, are of widely different chemical constitution, and consequently vary considerably in their power of resisting the further action of oxidising and hydrolytic agents. To follow up these cellulosic products into the region of specific variations, is a special study in itself, and further investigation must, therefore, be reserved: it is sufficient here to have indicated that the various celluloses are not identical, and that the term is applied to an aggregate of unknown components, obtained as the residue from the treatment above described.

Mercerising.—The action of concentrated solutions of the alkalis upon the vegetable fibres is an important feature in the diagnosis of their composition. The structural modification which the cotton fibre undergoes under this treatment was originally studied by Mercer, and hence the term "mercerising," by which the process is known. In the compound fibres, i.e. those which are made up of a number of fibrils aggregated

into a bundle, and of such bundles, as we shall presently see, the greater proportion of the vegetable fibres consist, the action of the alkali often causes a very profound structural change, not only dissecting the bundles, but altering the contour of the fibrils. So far as the chemistry of the action has been made out, the hydration changes which it sets up are in the direction of resolving the fibre substance into cellulose and non-cellulose. For the present, however, the action has been studied empirically, and it has not been further investigated than in regard to the loss of weight sustained. The fibre is thoroughly wetted with a concentrated solution (33 per cent. Na_2O) of the alkali, which is allowed to act for one hour. The fibre is then thoroughly washed, dried, and weighed. It is of interest to study the progress of the action of the alkali under the microscope, the specimen being mounted in the concentrated solution. See Fig. 24.

Nitration.—Cotton, when treated with concentrated nitric acid, is converted into explosive compounds, which are now recognised to be nitrates of cellulose. All the celluloses are similarly acted upon, and the study of the resulting compounds is a necessary feature of the diagnosis of the fibre substances.

It is necessary, for the purpose of a more exact comparison, to adopt some uniform, arbitrary method of treatment: we have adopted that of exposure for one hour at the ordinary temperature, the "nitrating" acid being composed of a mixture of equal vols. of concentrated nitric (s. g. 1·42) and sulphuric (s. g. 1·74) acids. The differences to be observed in the action of this acid on the various fibres are considerable, and form an important feature in their comparative investigation. Most important is the increase of weight occasioned, by union with the acid molecule. In some cases this is more than counterbalanced by loss due to conversion into soluble products; with such exceptions, however, and they are few, the nett increase is from 5–55 per cent. The weights obtained, in percentages of the dry fibre substance, will be found to be in intimate correlation with the other chemical constants of the several fibres. For the present we have confined our attention to this increase of weight under "nitration," leaving to future investigation the determination of the special characteristics of the several nitrates. A general external characteristic of these products is worthy of note here, that is colour: the ligno-cellulose give bright orange-coloured nitrates, the pecto-cellulose, on the other hand, colourless derivatives. Generally it will be found that a great deal of information concerning the constitution of a fibre is obtained by the study of its "nitration," and we lay more especial stress upon it, as we have not seen it anywhere recommended to be included as a necessary part of the investigation of the vegetable fibres.

Combustion. Carbon Percentages.—The vegetable fibres are composed of carbon, hydrogen, and oxygen as ultimate constituents, the latter being present in the atomic ratio 2 : 1 and the carbon appearing as some multiple of 6; the general formula for the composition of the fibre substance is therefore $C_{6n}H_{2m}O_m$. The quantity of hydrogen in percentage of the substance varies from 5·5 to 6·3, and therefore within such limits that particular estimations of this constituent are unnecessary. The determination of the carbon by the ordinary process of combustion is an elaborate process, and we have therefore substituted a rapid method, of which a preliminary account was given in the 'Chemical News.' The process consists in burning the substance with chromic anhydride in presence of sulphuric acid, and leading over the gaseous products (CO and CO_2) into an apparatus in which their volume can be exactly measured. The two oxides of carbon having the same volume, the quantity of carbon in unit volume is independent of the composition of the gas, which therefore only requires to be measured. As a further account of this method and apparatus will shortly be published, we need not enter into further detail here. The carbon in the typical (cotton) cellulose is 44·4 per cent.; the compound celluloses, on the other hand, range themselves for the most part into two groups: (1) of lower carbon percentage (40–43), (2) of higher (45–50); in the former the pecto-celluloses are included, the ligno-celluloses in the latter. As one of the prominent chemical constants of the fibre substance, therefore, we have included it in our scheme of investigation.

Acid Purification.—The object of this treatment is to clean the fibre and remove accidental impurities, while occasioning the minimum loss of weight and therefore alteration in com-

		Moisture.	Ash.	Hydrolysis.		Cellulose.	Mercerising.	Nitration.	Acid Purification.	Carbon Percentage.	Remarks.
				a.	*b.*						
A.	Linum U. (Flax) ..	9·3	1·6	14·6	22·2	81·9	8·4	123·0	4·5	43·0	European product.
	Girardinia H. (Nilgiri nettle)	7·3	1·5	2·5	9·7	89·6	3·7	160·7	2·5	44·0	
	Boehmeria N. (Rhea)	9·0	2·9	13·0	24·0	80·3	11·0	125·0	6·5	..	
	Calotropis Q.	7·3	2·5	13·0	17·6	76·5	..	153·5	8·5	44·0	
	Marsdenia T.	4·5	1·5	6·2	10·1	88·3	4·6	131·0	0·8	44·6	
	Crotalaria J. (Sunn Hemp)	8·5	1·4	8·3	11·7	83·0	11·3	150·5	2·7	44·3	
B.	Corchorus C. (Jute) ..	10·3	1·1	13·3	18·6	76·0	11·0	128·0	2·5	47·0	
	Sida R.	10·7	0·6	6·6	12·2	83·1	6·6	137·2	0·4	45·2	
	Abutilon A.	9·1	0·8	15·0	19·5	75·0	21·7	141·0	2·1	44·3	
	Abroma A.	10·6	0·4	5·2	10·9	80·0	19·2	132·0	5·1	46·2	
	Urena L.	10·7	1·8	11·9	18·5	77·7	13·6	..	4·0	..	
	Pavonia Z.	8·8	3·4	11·0	13·5	74·7	14·2	107·6	6·4	..	
	Hibiscus C.	10·6	2·2	14·0	19·5	73·0	16·0	..	..	..	
	Hibiscus E.	10·7	1·5	9·8	14·2	74·0	9·6	..	3·4	45·2	West Indian Mahoe.
	Grewia O.	10·6	2·2	8·4	13·4	72·0	9·7	123·0	3·4	43·9	
C.	Agave A.	10·5	1·4	10·0	20·0	75·8	11·0	109·8	1·1	44·9	
	Sansevieria Z.	9·7	..	12·0	16·5	73·1	..	106·0	2·5	44·5	Specimen from Ceylon
	Musa P.	13·4	..	11·0	33·0	64·6	11·0	91·3	4	..	
	Furcrœa C.	12·2	..	..	11·8	70	..	104	..	..	Specimen from Ceylon

		Moisture.	Ash.	Hydrolysis. a.	Hydrolysis. b.	Cellulose.	Mercerising.	Nitration.	Acid Purification.	Carbon Percentage.	Remarks.
*D.	Dendrocalamus S. † ..	11·3	1·1	21·5	27·6	72·0	13·1	107·0	0·8	..	
	Guazuma T.	9·0	3·1	12·2	14·8	70·2	10·4	122·0	0·3	45·2	
	Kydia C.	10·9	2·5	13·2	25·2	70·2	7·2	..	4·3	..	
	Parkinsonia	12·5	..	..	..	65·2	..	..	..	..	
	Anona S.	8·2	1·4	..	12·1	62·3	8·1	135·0	3·0	43·9	
	Hardwickia B.	13·3	..	..	..	63·4	..	..	..	..	Bast ribands.
	Sterculia	..	..	..	..	36–48	..	..	..	..	S. urena, S. colorata, S. villosa.
	Ficus Inf.	10·9	7·1	18·3	27·5	59·7	36·6	101·0	5·6	41·2	
	Ficus Rel.	10·0	7·9	22·6	46·8	41·2	..	..	..	..	
	Edgeworthia	13·6	3·9	21·2	34·7	58·5	16·5	126·0	8·3	41·8	
	Helicteres I.	10·8	3·1	12·0	20·2	56·7	..	..	..	..	
	Sesbania A.	12·9	..	..	..	58·6	..	..	..	..	
	Bauhinia V.	10·0	6·2	38·9	61·6	52·5	26·2	93·4	..	40·7	
	Laportea C.	9·5	12·0	24·4	46·5	53·4	22·6	113·6	14·3	40·2	
	Saccharum M. †	10·3	..	..	38·3	49·2	..	..	..	..	
	Melia A.	12·5	7·9	21·7	48·9	45·4	16·1	..	14·0	..	
	Maoutia P.	11·2	8·2	..	62·7	32·7	..	..	..	..	Bark strips.
	Eriodendron H.	12·4	9·5	..	50·5	33·6	7·5	..	6·1	..	Bark strips.
	Daphne P.	14·1	..	..	..	22·3	..	..	..	..	Bark strips.

* Doubtless the occurrence of many of the above, e. g. Maoutia Puya, one of the Urticaceæ, in this group (D), is explained by the faulty preparation of the particular specimen. The arrangement is in the order of the cellulose percentage. This, again, would have been in all cases considerably affected by a more complete separation of fibre from adhering tissue and "encrusting" substances.

† These two specimens monocotyledonous. The remainder bast tissues of dicotyledons.

position. For this purpose acetic acid (20 per cent.) was chosen, the fibre being heated with the acid to the boiling-point, then removed and washed first with alcohol and lastly with water; dried and weighed. The loss in weight sustained is thus determined. It was in the fibre thus purified that the carbon percentages were determined.

Having thus described the method, it only remains to point out in what more important respects it differs from those of other investigators. It is based upon the principle of selecting for comparative estimation only the prominent general points of similarity and distinction. These are:—(1) Hydrolysis, (2) cellulose by chlorination (or oxidation) and solution of the products, (3) "nitration," (4) carbon percentages. In regard to the details of treatment, our selection is necessarily arbitrary, but, we venture to think, not merely empirical. The proof of this, and an attestation of the soundness of the method, is to be found in the correlations which are brought out in the tabulated statement of results.

For the complete elucidation of this table and the classification of the fibres which it introduces, we must now deal briefly with our subject from the complementary aspect of minute structure and the microscopical methods by means of which it is studied.

Excepting the seed hairs, typified by cotton, which are isolated elongated tubular cells, attached to the hard seed envelope, the vegetable fibres are compound structures, the unit being the bast fibre-cell. These units are built up into bundles, according to the two main types of mono- and dicotyledonous growth, in illustration of which we may cite the following from amongst the micro-photographs:—

Flax.—Bast of dicotyledonous species *Linum*.
1. Isolated fibre-cell. Fig. 14.
2. Fibres *in situ*. Fig. 13.

Jute.—Bast of dicotyledonous species *Corchorus*.
1. Isolated fibre-cell. Fig. 6.
2. Cross section of bundle. Fig. 22.
3. Bundles *in situ* in the plant. Fig. 2.

In the dicotyledons, therefore, the cells are built up into bundles, in which they are more or less firmly compacted together, and these are aggregated together and localised in the plant as a fibre tissue, between the wood and the cortex. The arrangement of the fibres and bundles is subject to endless variation, but these variations are within the limits of a general disposition such as that described.

In the monocotyledons, on the other hand, the typical structure is much more complex in both respects; (1) the bast fibres are built up together with vessels—cells which are differentiated altogether differently—into a composite structure known as a fibro-vascular bundle; (2) the disposition of these is irregular, the bundles not being localised into a tissue. These points are exemplified in the following drawings.

Sugar cane (stem). F.v. bundles of monocotyledonous species.

(1) F.v.b. isolated. Fig. 5.

(2) Cross section of stem showing bundle *in situ*. Fig. 4.

Phormium tenax (leaf).

Cross section of leaf. Fig. 3.

Before proceeding to discuss the general bearing of these structural relationships, we will treat briefly of the microscopical methods by which they are elucidated. As regards the preparation and mounting of the objects for examination, the only point which needs mention, as in any way novel, is the mode of cutting the sections of the fibres, or fibre bundles, and of determining the length of the ultimate fibres.*

The fibres or bundles, after having been arranged carefully in order to keep them as far as possible parallel, are thoroughly dried in the water bath, saturated with asphalte varnish, and then worked into a pencil by squeezing between the finger and thumb. On exposure to the air for two or three days, the pencil will become hard, and may then be inserted in the microtome and cut in the usual way.

For the determination of the length of the ultimate fibres, the cellulose, isolated by the method given under "estimation of cellulose," was taken in each case, thereby avoiding an error very likely to occur when it is attempted to obtain ultimate fibres by teasing out from a specimen treated with alkali only, according to Vétillart.

For the representation of the microscopic preparations, the

* It has been suggested to limit the term *fibre* to the ultimate fibre-cell, using for the fibre-bundle the appropriate term *filament*; these we have adopted.

two methods were open, viz. a camera drawing and photographic reproduction. We chose the latter, as more convenient, and in all respects more trustworthy.

The following is a brief description of the micro-photographic apparatus and the method of working:—

The camera A is a bellows camera of the ordinary construction fitted to a base-board B, 3 feet in length. The front C is so arranged that it slides easily along a couple of slots D on either side of the base-board. By adjusting a screw (not shown in the figure) it can be firmly fixed at any point. The back E, carrying the ground glass, can also be moved along the base-board by means of a rack and pinion. Inside the rack, and extending the whole length of the base-board, is a scale divided into inches and eighths, so that the position of the back and its distance from the front of the camera can be readily ascertained. The front carries a wide brass tube covered on the outside with black flock paper, into which the body of the microscope passes easily. Outside the microscope tube, and fitted on to it concentrically, is a wider tube of brass blackened on the inside, the two tubes forming a perfectly light-tight and self-fitting joint; the whole arrangement being arranged as shown in section in the accompanying sketch.

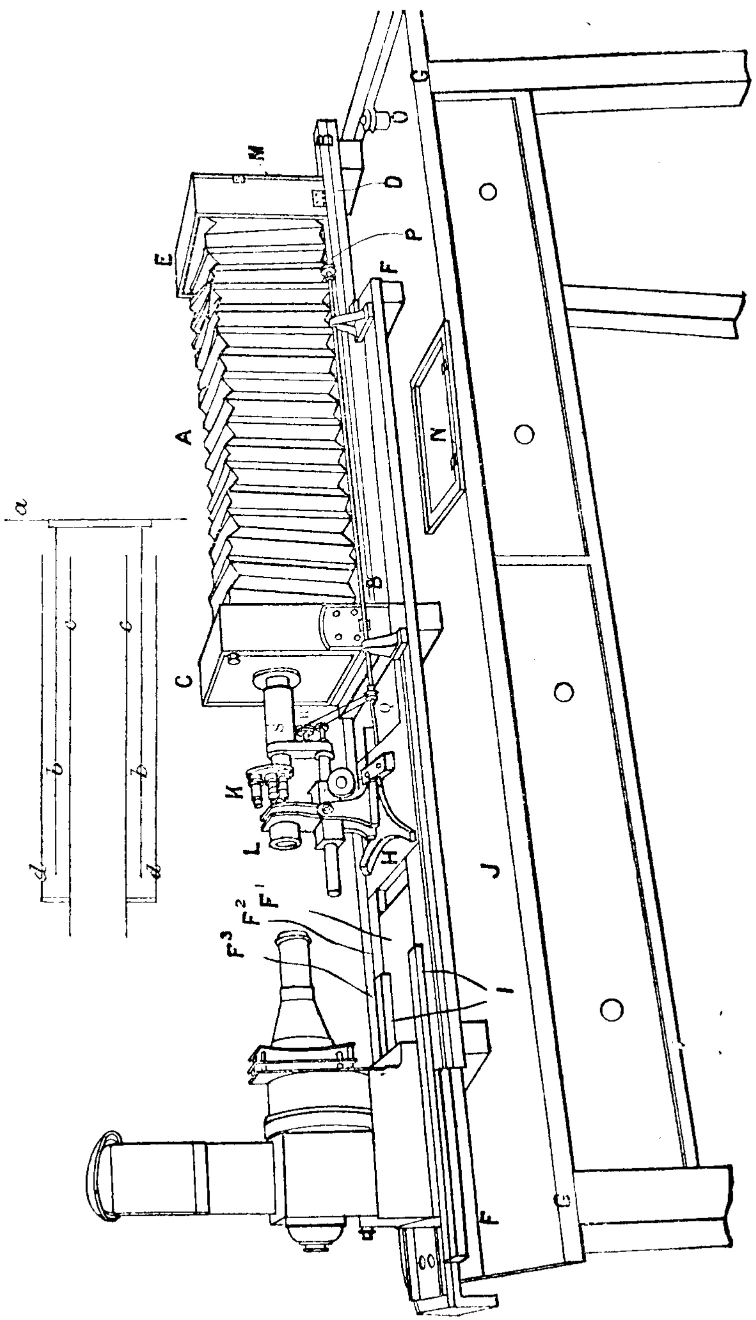
The base-board of the camera is secured by thumb-screws to the larger base-board F, which in its turn is screwed firmly to the table G.

The base-board F is composed of three separate parts, F′, F″, and F‴, sliding smoothly into each other; when fully extended it measures 8 feet.

The microscope is fixed by means of wooden feet and screws to the platform H, which forms a part of F‴. By withdrawing F″, the distance of the microscope from the front of the camera can be varied at pleasure, the arrangement as shown in section being sufficiently long to allow of this, without admitting light.

The source of light is placed upon F′, which is furnished with a pair of parallel runners I, along which it can travel. An inch scale is placed along the base-board to denote the distance of the microscope from the front of the camera, and also the distance of the source of the light from the object.

The microscope itself is an ordinary monocular instrument,



a. Front of Camera. b. Tube fastened to front of Camera. c. Tube of Microscope. d. Wider tube fastened to tube of Microscope.

fitted with mechanical stage, coarse and fine adjustment, sub-stage for carrying achromatic condenser, &c.

For convenience of working, the microscope is fitted with a nose-piece K, carrying three objectives.

Before commencing the actual work of photographing, a table is constructed, of the positions of the back of the camera on the base-board corresponding to different enlargements, and marks are made upon the scale with which the base-board of the camera is furnished.

The source of light to be recommended is for the higher powers, an ordinary triple-wick oil lantern, and for low powers, such as the inch or three inch, an argand gas-burner.

For certain objects the light is placed at a considerable distance (2–3 feet) from the object, as it was found that if the object be too brightly illuminated, the photograph obtained is wanting in detail. Each object requires a separate adjustment of the light according to circumstances. In certain cases the light is concentrated on the object by an achromatic condenser L, a small diaphragm being used to increase the definition. For the lower powers no condenser is used, a small diaphragm being inserted in the substage.

The method of procedure is as follows:—

The object being placed in position on the stage, the front of the camera is removed far enough to allow the operator to observe it in the ordinary way, an eyepiece being inserted into the microscope for the purpose. The part which it is desired to photograph having been found and placed in position, the eyepiece is withdrawn, and the front of the camera replaced and secured in position by means of the screw provided for the purpose.

The object is then brought into focus roughly on the ground glass by means of the coarse adjustment. Owing to the distance of the microscope from the ground glass this operation is performed by an assistant, who also adjusts the object by means of the mechanical stage until the image corresponds in position with that occupied by the sensitive plate, marks being made for the purpose upon the ground glass. The ground glass is then removed, and a piece of plain glass N fitted into a wooden frame, substituted. The object is then carefully focussed with the glass O, the focus of which, when in contact with the outer surface of the plain glass, exactly corresponds with the inner surface. A number of fine diamond marks are made on the glass for the purpose. The focussing is effected by means of the milled head P fixed on the rod Q, which, by means of the thread R, actuates the fine adjustment S.

This having been accomplished, the back, containing a sensitive plate, is placed in position and the shutter withdrawn.

The exposures vary from five to forty-five minutes, according to the objective employed, the light, and the thickness and colour of the object.

In certain cases it is necessary to withdraw the objective from the position of best visual focus in order to obtain the actinic focus. In most cases, however, the foci are found to correspond.

The micro-photographs reproduced from the original negatives are, we certainly hold, more trustworthy representations of structural details than the diagrams usually given, for instance, by Vétillart. For the purposes of records, such as the present report, these representations are especially to be preferred, as, if generally adopted, a strict comparison could be made between the observations of various investigators.

We may now draw a few general and practical deductions from this study of microscopic details.

The bearings of these structural features upon the very important technical question of isolation and application of the fibres, are both obvious and direct. In the first place, the superiority of the dicotyledonous fibres is manifest, on the grounds (1) of comparatively easy separation, and (2) structural simplicity of the fibre bundles. The separation of these fibres from the contiguous tissues, wood and cambium on the one side and cortical parenchyma on the other, is assisted by the preliminary process of retting, a fermentation induced by immersion in stagnant water. The purpose of this is to weaken the surrounding cellular tissue without injury to the fibre. These, however, are not so dissimilar chemically that the changes which are set up should proceed to the detriment of the former only: indeed, observation has sufficiently shown that the fibre substance is attacked, and that the process needs most careful regulation to reduce this to the satisfactory

minimum. The retting accomplished, the separation of the fibre is a question of a simple mechanical treatment. The several applications of the fibres in the textile arts is conditioned in the first instance by their fineness, or the degree of fineness to which, by comparatively simple and inexpensive means, they can be brought. Second in importance is the uniformity in length and diameter of the spinning unit. This unit is not the ultimate fibre-cell (excepting of course in the case of cotton), but a bundle of these. Consequently the conditions in question are best fulfilled, other things being equal, by the fibre whose bundles are the least complex. A superficial examination of the flax and jute fibres will reveal the structural causes of the superiority of the former. But another most important factor remains to be noticed, that is, the length of the ultimate fibre-cell; for, although not the spinning unit, still it is in a very direct sense the essential factor of the strength and durability of the manufactured goods.

It has not yet been pointed out that with the removal of the non-cellulose constituents of the several fibres the fibre bundles are disintegrated, i. e. the cellulose of the fibre is obtained in the form of individual cells, isolated from their previous union. The bleaching processes practised in the arts tend therefore to resolve the fibre bundles into the component units, and when complete, i. e. when a pure cellulose is obtained, they do so completely. On this view compare the ultimate fibre of jute, with its small length of 3 mm., with that of flax, with its length of 40 mm., or a length equal to that of cotton, and it is not difficult to understand why in the one case bleaching means "rotting," whereas in the other the superior length enables the mechanical effect of the spinning to survive the disintegration of what was the spinning unit. It should also be pointed out that the bleaching process is only intensifying, by achievement within a short space of time, what the ordinary conditions of the life of a textile fabric—the alternate atmospheric oxidation and boiling in alkalis—will gradually accomplish: thus the length of the ultimate fibre is of first importance from whatever aspect regarded. We have therefore now taken into account the chief factors, chemical and structural, of the value of a fibre, or what is the same thing, of the applications which it finds in the arts. It is scarcely necessary again to revert to the discussion of the inferiority of the monocotyledonous fibres; we need only sum up the chief points, upon the lines of the argument just concluded: (1), the difficulty of isolation from the plant, and (2), the extreme variations of the bundles resulting from their heterogeneous composition.

The classification under which the chemical results are recorded, involves a further distinction. There are a number of fibrous raw materials, both of mono- and dicotyledonous origin, in which the fibres are built up into still more complex aggregates, and from which the ultimate fibre-cells cannot be isolated by a simple mechanical treatment. With these substances, therefore, a chemical process of resolution is necessitated: the ultimate fibres are then obtained in the form of a heterogeneous mass or pulp, available only for paper-making purposes. To this belong (of dicotyledonous origin) such bast tissues as Adansonia, Linden, Sterculia, and of monocotyledonous origin, esparto, and other grasses, and the stems of cereals.

The chief structural features of the several classes are therefore as follows:—

Raw Fibrous Materials.		Monocotyledonous.	Dicotyledonous.
	Fibres.	*Anatomy.* Fibro-vascular bundles Bast fibres and vessels, sometimes enclosed in cellular sheath. Component fibres very numerous.	*Anatomy.* Bundles of bast fibres only. Component fibres few.
		Composition. (C) Mixed pecto, ligno (adipo) cellulose.	*Composition.* A. Pectic (sometimes slightly lignified). B. Lignified (more or less pectic).
	Fibre aggregates.	*Anatomy.* Whole plants or parts of plants.	*Anatomy.* Bast tissues. Bast fibres, with medullary rays and parenchyma.
		Composition. (D) Mixed pecto, ligno (adipo) cellulose.	*Composition.* Pecto and ligno-cellulose.

While we are fully sensible of the advantage we have derived from the above classification, if only in co-ordinating the results of our investigations, we are equally desirous of

avoiding false estimates of its value. The lines cannot be sharply drawn, and the grouping of the fibres which they define are not more than typical and approximate.

The special structural features of the various fibres are necessarily of a character requiring individual description, and they will be dealt with seriatim, and chiefly by means of the microphotographs. We may anticipate this treatment in detail by a few general considerations. We have already spoken of the length of the ultimate fibre from which, with the diameter (i. e. sectional area), the outline of form is at once known. Generally the fibre cells are tubulated and cylindrical, though various modifications of this primary form will be noticed. In the dicotyledonous bast fibres the polygonal type prevails, and the cell walls are in many cases thick, and the central canal consequently small. Exceptional length is to be found in these only, and then in but very few; it is moreover remarkable that lignification is correlated with short length of fibre, the long fibres appearing only in Division A. (See p. 24.) In the monocotyledonous fibres, the bast cells are often extremely fine, thin walled, and generally cylindrical or oval; the length in the several fibres varies from 1 to 12 mm.

As regards the inner structure of the fibres, the sections frequently reveal the existence of concentric zones in the cell wall, and micro-chemical tests—more especially with aniline sulphate and iodine solutions—reveal differences of chemical composition in these zones. By rupturing the cell wall, as in the process of "beating" pulp for paper-making, it is decomposed into fibrillæ, which may be considered as the ultimate structural components of the fibre wall; the arrangement of these follows two main types, viz. (1) parallel to the long axis of the fibre, as in the case of flax; in the second the disposition of the fibrillæ indicates a spiral or membranous structure.

All these points will be found very fully discussed, both in their scientific and technical bearing, in M. Vétillart's treatise before alluded to.

We have already stated that M. Vétillart avails himself only incidentally of chemical methods; he employs micro-chemical tests for the identification of the fibre substance, i. e. for such identification as a purely qualitative test can afford; and he attaches, nevertheless, sufficient importance to the results of this micro-chemical examination, as to make it the basis of his classification of the fibres. On the other hand, we find that those who have adopted a quantitative chemical method of investigating these cellulosic products have been in most cases chemists first and microscopists afterwards, so that questions of minute structure have been treated by them as of secondary importance. Further, we find that in adopting quantitative methods, there has been too little inquiry into the precise value of the quantities determined in throwing light upon the special chemistry of the fibre substances. Thus the loss of weight on treatment with solvents, such as alcohol and ether; the determination of "cellulose" by such a process as Schultze's, viz. digestion with nitric acid (dil.) and potassium chlorate; the still cruder process of estimating as a measure of cellulose what is termed "crude fibre," commonly practised in agricultural analyses; are all of a purely empirical character, and really of little value in regard to the information they afford, theoretical or practical.

So long, of course, as we know so little of the actual constitution of this group of natural products, our methods of investigation must be more or less empirical. Our present aim is therefore to assist progress from the more to the less arbitrary, in our chemical tests, and at the same time to insist upon the importance of the microscopic examination; and to show that the methods based upon this view are sound theoretically, because they lead to classifications which are simple and in harmony with physiological facts, and practically, because the quantities determined are in close correlation with deductions from practical experience, for which, therefore, they supply the rational basis.

PART II.

There are over 300 fibre-yielding plants in India. At least 100 of these afford strong and useful fibres, which are regularly used by the natives of India, and perhaps about thirty are worthy of European recognition. Cotton is of course by far the most important, and the manufactured cottons are the most valuable articles of import trade. The Indian foreign trade in cotton and cotton goods, during the year 1884–5, was valued at over 41,000,000*l.* (the rupee, for convenience, being calculated at par), and the total foreign trade in fibres (i. e. imports and exports) amounted to over 53,500,000*l.*, being a decline from the previous year of 1,000,000*l.* in the exports of raw cotton. The exports of Indian manufactured cottons improved during the year by nearly 1,000,000*l.*; jute remained, practically speaking, stationary; and the exports of raw silk, of wool, and the imports of paper fell off considerably. The Government imports of paper appear to be increasing; last year they amounted to 137,109*l.*, or 100 per cent. greater than in 1881–2.

Although steam machinery has driven hand-looms largely out of the market, there still survives in every village the weaver who, with the crudest of appliances, produces from home-spun or power-loom yarn a coarse though very str[illegible] durable fabric, ornamented with a simple but [illegible] Of the extent of the internal trade in fi[illegible] can be learned. It should not be for[illegible]ever, that the above figures refer exclusively to the foreign trade, and that over and above the amount of imports and exports there exists an enormous trade in Indian manufactured goods. The extent of this internal trade Government has hitherto failed to determine, but large tracts of country may be found where the people are clad almost entirely in local-made garments. In fact, from the stubbornness of the British manufacturer to imitate native qualities, shapes, and patterns, European yarns woven on the Indian hand-looms have made greater progress than European goods. This peculiarity has given birth to the Indian cotton mills—mills devoted almost entirely to supplying the native weaver with his yarn.

The following tabular statement of the more important fibres will give some idea of the foreign trade:—

THE TEXTILE INDUSTRIES FOR 1883-4 AND 1884-5.

		1883-4. Rupees.	1884-5. Rupees.
Cotton, raw	Exports	14,38,31,278	13,28,63,673
	Imports	9,95,820	16,25,980
	Total	14,48,33,098	13,44,89,653
Cotton, manufactured	Exports	2,85,31,710	3,33,80,297
	Imports	25,10,83,306	24,55,78,331
	Total	27,96,15,016	27,89,58,636
Jute, raw	Exports	4,59,26,353	4,66,13,684
	Imports	1,267	1,364
	Total	4,59,27,620	4,66,15,048
Jute, manufactured	Exports	1,33,41,447	1,54,38,696
	Imports	4,14,491	3,61,943
	Total	1,37,55,938	1,58,00,639
Flax and its manufactures	Exports	5,457	..
	Imports	11,15,486	10,55,745
	Total	11,20,943	10,55,745
Hemp and its manufactures	Exports	6,91,826	5,85,808
	Imports	2,09,335	2,55,474
	Total	9,01,161	8,41,282
Coir and its manufactures	Exports	15,30,629	21,43,241
	Imports	1,06,630	1,13,554
	Total	16,37,259	22,56,795
Cordage and rope	Exports	4,92,068	3,53,389
	Imports	3,90,584	3,52,413
	Total	8,82,652	7,05,802

THE TEXTILE INDUSTRIES FOR 1883-4 AND 1884-5—*continued.*

		1883-4. Rupees.	1884-5. Rupees.
Paper. Exports	Raw materials	3,63,659	3,70,533
	Manufactured	1,733	..
	Total	3,65,392	3,70,533
Imports	General	37,49,127	35,21,026
	Government	16,68,148	13,71,095
	Total	54,17,275	48,92,121
Silk, raw	Exports	62,76,117	46,35,613
	Imports (mostly from China)	96,95,749	74,75,633
	Total	1,59,71,866	1,21,11,246
Silk, manufactured	Exports	28,57,336	32,85,627
	Imports	1,20,13,481	1,27,33,536
	Total	1,48,70,817	1,60,19,163
Wool, raw	Exports	75,58,409	71,35,760
	Imports	6,51,368	6,18,212
	Total	82,09,777	77,53,972
Wool, manufactured	Exports	12,07,003	11,83,427
	Imports	1,21,70,531	1,23,43,397
	Total	1,33,77,534	1,35,26,824
	Grand total	54,68,86,348	53,53,97,459

In this report a classification has been adopted to suit the particular collection of fibres presented for examination, but for more comprehensive investigations we would suggest a scheme such as the following, which gives a complete survey of all the vegetable products of a fibrous nature.

Group I. Bast Fibres of Dicotyledons.

Class I. Fibres suited for higher textile uses, by reason of length of ultimate fibres and absence of lignification.

Class II. Fibres of lower textile value, owing to shortness of ultimate fibre and lignification.

Class III. Fibres inferior to the above, to be used only by the rope-maker or paper-manufacturer. In this class the fibrous wastes obtained in the working of members of Classes I. and II. would be included.

Group II. Monocotyledonous Fibres.

Class I. Fibro-vascular bundles. Applications to textile purposes according to degree of fineness and divisibility.

Class II. Whole stems or parts of plants, available only for coarsest textile uses and for paper-making.

Group III. Miscellaneous.

Includes seed-hairs (flosses), the tomentum from leaves, epidermal strips (Raffia), &c.

Within each of the groups of the original classification (Part I.) the fibres specially examined will be discussed in the alphabetical order of their scientific names instead of in their supposed relative values. This course has been presumed to be at once the simplest and the least open to error, since it must be admitted that while chemical and microscopic peculiarities indicate the lines of possible utility, practical difficulties often lower the value of one fibre, just as experimental tests may raise another. Thus, for example, rhea fibre has still to be separated from the bark and the gum at a price that will pay, and the degree to which a rhea crop exhausts the soil would present a formidable obstruction to an extended trade in that most valuable fibre, even were the mechanical difficulties overcome. So in a like manner a lower position has been assigned to the *málú* fibre (the fibre of *Bauhinia Vahlii*) than it may practically be found to deserve. The ultimate fibres are short and lignified more or less, but in spite of these objections the fibre possesses properties that may commend it to certain industries.

Division A.

BŒHMERIA NIVEA, H. & A.; URTICACEÆ.—Rhea grass; China grass; *Ria*, Beng.

In the plant.—Fig. 7; fig. 8. The bast is a continuous ring; fibres in loose contact. Ovoid to polygonal, cavity large, very variable, mean diameter greater than flax.

Textile filaments.—Average number in bundle, 3; frequently single. Section as in fig. 8.

Ultimate fibre.—Exceptional length, 40–200 mm.; greatly in excess of any fibre.

Reaction (Vétillart).—Blue with iodine and sulphuric acid.

This yields one of the finest, and at the same time strongest, fibres in Asia. In India there are many species of Bœhmeria, however, and it seems probable that, in concentrating our attention on conquering the difficulties against introducing this particular species, we may have overlooked others of equal merit. Nearly every province in India has one or two indigenous species of rhea, and while most of these are regularly resorted to by the natives as sources of strong fibre, the fibres obtained from them are quite unknown to Europeans. An effort was made to bring to the Colonial and Indian Exhibition as many of these as could be procured, but if longer time had been given the set might have been much more numerous. The reader is, however, referred to *Maoutia* and *Villebrunea* as two of the most valuable rhea-yielding plants. The particular specimens, however, exhibited were very inferior.

To Dr. J. Forbes Watson is due the credit of having procured an international interest in this wonderful fibre. A summary of all the reports and publications which have appeared on the subject of rhea grass will be found in Watt's 'Dictionary of the Economic Products of India' (vol. i. pp. 468 to 483). It is not deemed necessary to reprint here the voluminous information now available, but in submitting the results of our personal investigations, we feel confident the greatest hopes may be held out regarding the plants allied to rhea. Although the collection of fibres shown at the late Exhibition was marvellously complete, it is believed the allied rhea fibres were less perfect than many others of a far inferior character.

CALOTROPIS GIGANTEA (AND PROCERA), R. Br.; ASCLEPIADEÆ.—*Madar*, Hind.; *Aranda*, Beng.

In the plant.—Fig. 9. Fibre disposed in aggregate of 50–100. Cortical parenchyma largely developed. Fibres oval, loosely coherent.

Textile filaments.—Short length (8–16 in.) owing to nodes of stem; bundles easily divided.

Ultimate fibre.—Length, 10–30 mm.; ends tapering.

Reaction (Vét.).—Blue-violet with iodine and sulphuric acid.

A small shrub, common throughout India. The silky floss from the apex of the seed is used for stuffing pillows, and has been proposed as a paper fibre. Attempts have been made to spin this silky floss, but it has been found too short in staple, and too light for ordinary purposes. The bast fibre from the bark has, however, attracted considerable attention, and is constantly spoken of as one of the best of Indian fibres. The chief difficulty in utilising it seems to reside in the inability to rapidly and cheaply separate and clean the fibre, and in the shortness of the fibre when extracted.

A very great interest was shown in this fibre during the Colonial and Indian Exhibition, and a summary of the action taken is contained in the following extract:—"The world has heard so much of the *madar* fibres that it may be viewed as presumptuous on my part to desire to go back upon the unfavourable verdicts which experts have passed upon them. It is well known that the stems of this plant afford one of the strongest and finest of vegetable fibres, and one of the most beautiful. The great difficulty is to separate this fibre from the stems, and, indeed, so great is this difficulty that the idea has practically been abandoned. By nitrating *madar* fibre, however, a substance may be produced which can with difficulty be detected from silk. It has all the gloss and softness of silk, and would seem so valuable that, in this state, it could well afford to bear an expensive process of separation.

"I desire your attention not so much, however, to the possibilities of *madar* bark fibre as to the floss found attached to the seeds. This has been pronounced too short and too light to be worked on machinery. But I have begun to suspect that we can correct these defects to a large extent. The plant is wild along country roadsides in India, luxuriating on every bit of waste sterile land. No person, as far as I am aware, has thought of cultivating it. An important Lancashire spinner has assured me, however, that even in its present state he can use any amount of the fibre; all he requires is a uniform and steady supply. We have agreed that this can never be secured from a wild plant, which has to be collected by wandering along miles of roadsides. Through the kindness and co-operation of a missionary friend, however, I am at present having a few acres of inferior land cultivated with *madar*, and we are hopeful of being able to prove to the poor Santals of Bengal that this crop would

pay them far more than some of the things they and their forefathers have been in the habit of growing. If this can be done uniformity and continuance in supply may not only be secured, but it may be confidently hoped that, with careful selection of seed, after a few years we may educate the plant into becoming obedient to man's skill. Our cultivated *madar* may yield a floss that will have none of the defects complained of. If this can be done, I am satisfied my friend will do it, for I know of no more careful and painstaking person in India than the gentleman who has most generously undertaken to pioneer the introduction of this new annual crop."—*Watt, 'Journal Society of Arts.'*

Cannabis sativa, Linn.; Urticaceæ.—Hemp; *Bhang*, Hind. and Beng.

As stated by Dr. Watt, *infra*, this fibre has never been successfully produced in India.

The peculiar microscopic features, as explaining the inferiority of the fibre produced in these latitudes, are exhaustively discussed by Vétillart in his treatise, pp. 72–75.

The fibre was not included in our list for laboratory investigation.

Most probably a wild plant in the mountain tracts of Northern India. It is chiefly, if not exclusively, cultivated on account of its narcotic principle. Several attempts have been made to use the stems rejected after the separation of the narcotic, but these have uniformly failed. It has been found that the narcotic-yielding plant affords only a miserable fibre, and in the plains of India, at least, it seems impossible to produce a profitable crop of hemp fibre. On the hills, especially at Kumaun, the plant is often cultivated for its fibre, and coarse cloth is made of it by the hill people. At the beginning of the present century every effort was made by the Government to establish in India a hemp industry, but the idea seems to have been abandoned in favour of Sunn hemp and other indigenous fibres. It is probable that failure would attend any effort in this direction, even should a demand arise for new supplies of hemp. The climate of India seems to favour the production of the narcotic at the expense of the fibre. Fiscal difficulties would also have to be overcome of a very formidable character, for the Government of India would never permit a greatly extended cultivation of a plant, the leaves and flowers of which yield so pernicious a narcotic. From the Government reports of the foreign trade of India in 1884–85 there would appear to have been 9092 cwt. of hemp, valued at R2,14,718, imported, and 73,029 cwt., valued at R5,82,679, exported. How far these figures allude to the true hemp it is impossible to ascertain, for it must be recollected that a series of widely different fibres are often spoken of as "hemp," such as Manilla hemp, Sunn hemp, &c.

CROTALARIA JUNCEA, Linn.; LEGUMINOSÆ.—*Ordinary Indian names:* Sunn hemp; *San*, Beng.; *Ambádi*, Bomb.; *Jenappa-nar*, Tam.; *Jenapa-nara*, Tel.; *Paiksan*, Burmese; *Tág*, West India. *Commercial names:* Sunn, Indian hemp, brown hemp, Bombay hemp, Wucku or Travancore flax, Jubalpur hemp, Konkan hemp, &c., &c.

Textile filaments.—Fig. 10. Bundles of 20–50, not easily divided. Fibres polygonal, cavity small. Fibre substance shows well marked concentric rings.

Ultimate fibre.—Fig. 11. Length, 3-5 mm.; ends tapering abruptly; characteristic markings, spiral.

Reaction.—With iodine and sulphuric acid, mixed blue and brown; with aniline sulphate, yellow streaks; shows lignification. This fibre may be regarded, both chemically and structurally, as intermediate between those of Divisions A and B.

An annual plant belonging to the pea family, universally cultivated all over India on account of the strong, useful rope-fibre obtained from the twigs.

This is separated by retting the stems much after the same method as is practised with jute, only that experience has shown that the Sunn fibre is stronger when the plant has not only been allowed to flower, but to ripen its fruits and seeds. Opinions seem also to concur as to its being preferable to ret the stems soon after cutting, instead of following the practice adopted in some parts of South India, of drying them before retting. Indeed, it is recommended by the most successful cultivators to submit the thick ends of the stems to about twenty-four hours' retting before completely submerging the whole of the twigs. The coarse cloth made in Mysore from this fibre was in Dr. Buchanan's time, as at the present day, known as *Goni* (Gunny), a name almost exclusively applied in other parts of India to jute

cloth. Considerable ambiguity is caused by the numerous names given to Sunn fibre, as in some parts of the north-west provinces jute, and not *Crotalaria*, is known as Sunn hemp.

While Bengal is pre-eminently the jute-growing country, Western and Southern India seem to produce the better qualities of Sunn hemp, and it seems surprising that no effort has as yet been made in these presidencies to develope a Sunn hemp industry. Both Roxburgh and Royle showed beyond all doubt that the Sunn was a far superior fibre to jute, a fact confirmed by our recent chemical and microscopic investigations. Roxburgh showed that, while dry, a line of jute broke with a weight of 143, and, when wet, with 146; a similar Sunn line sustained 160 and 209. Royle has shown that a cord, 8 inches in size, of best Petersburg hemp, broke with 14 tons 8 cwt. and 1 qr., while a similar rope of Sunn only gave way with 15 tons 7 cwt. and 1 qr. He further demonstrated the slight deterioration of Sunn hemp as follows:—A rope made in 1803 broke with a weight of 6 tons 0 cwt. 3 qrs., whereas, when kept till 1806, it gave way with 5 tons 17 cwts. 0 qrs.

It is impossible to urge too strongly the claims of this much neglected fibre, a fibre which seems to have suffered severely through the immense success of jute obscuring for a time the properties of all other fibres. At the beginning of the century Sunn hemp held a much more important position than it does to-day, and all efforts to cultivate the true hemp in India were abandoned, from the impression that the so-called indigenous hemp was, for all practical purposes, of equal merit. During the Colonial and Indian Exhibition numerous inquiries were made as to why it was that so little of the better qualities of Sunn hemp were procurable. Mr. Collyer and several other brokers and merchants stated that their only difficulty in pushing the trade in Sunn hemp was their inability to procure a uniform and large enough supply. From these and many other considerations we strongly commend this well known fibre to the attention of the Government authorities of Western and Southern India. What encouragement they may be able to render may hopefully be anticipated to lay the foundation for a textile industry that may yet come to bear a creditable comparison with the jute trade of Bengal.

There are two or three allied species of plants all affording the Sunn hemp of commerce, but it is understood the better qualities are forms of *Crotalaria juncea*, which owe their superiority to climatic conditions and superior methods of cultivating and preparing the fibre. It should never be forgotten that while Sunn hemp may be used as a substitute for true hemp, the plants and fibres obtained from them are widely distinct.

GIRARDINIA HETEROPHYLLA, Decaisne; URTICACEÆ.—The Nilgiri Nettle; *Awa, alla, bichua*, Hind.

An exceedingly common, large, herbaceous plant of the forests of the warm-temperate regions. It is common throughout most of the hill districts of India and Burma, but especially upon the Himálaya.

There are two if not three distinct species, each of which yields an admirable fibre. *G. zeylanica* is the true Nilgiri Nettle, but commercially the fibres of all three have come to bear that name. The true Nilgiri Nettle is chiefly met with on the mountains of South India. *G. heterophylla* is the characteristic form of the plant met with on the Himálaya. This affords a fine, silky fibre, used in Sikkim and the Naga hills for ropes and coarse cloth resembling *gunny*. Roxburgh says of it: "The bark abounds in fine, white, glossy, silk-like, strong fibres."

A very serious difficulty, preventing an extended use of these strong fibres, is the stinging hairs of the plant. These cause great annoyance to the persons employed to extract the fibre, and even after being manufactured into cloth, the poisonous property has not been completely destroyed, but, on the contrary, often causes great irritation to the person wearing garments made of this cloth.

LINUM USITATISSIMUM, Linn.; LINEÆ.—Flax. Figs. 12, 13, represent sections of home-grown flax; it is introduced as the prototype of textile bast fibres. It is cultivated extensively in India for its seed. The attempts to produce the fibre, as in the case of hemp, have failed. (See *infra.*)

In the plant.—The bast is in a continuous ring; sometimes two concentric fibrous zones are developed, the fibres in which have different features. In many cases an aggregation into groups is noticed. The fibres are in loose contact, the cortical parenchyma is not largely developed.

Textile filaments.—Average number of fibres in bundle 5–10; easily sub-divided.

Ultimate fibres.—Fig. 14. Exceptional length, 25–40 mm. Two types: (1) the normal, small diameter, thick-walled and polygonal; (2) large, ovoid, with large cavity resembling rhea.

The well-known linseed oil is obtained from the seeds of this plant, and for this purpose it is extensively cultivated throughout India. The stems do not appear, however, to develope the fibre, and in no part of India is the plant specially cultivated as a source of flax. Whether this is due to the abundance of other fibres discouraging any effort to produce flax, or to the climate of India favouring the development of the oil at the expense of the fibre, or simply to the peculiar variety cultivated being an oil- and not a fibre- yielding form, does not appear to have been practically solved. We should be glad of an opportunity to thoroughly investigate this matter, and with the approval and co-operation of the Government of India would propose to procure a quantity of the best flax-yielding seed from two or three European countries. This we should simultaneously cultivate, half in India and half in Europe. If the Indian samples were cultivated and carefully reported on, according to an agreed upon plan, the produce would enable us to form some definite ideas. At the same time, it would be necessary to have selected samples of Indian linseed cultivated alongside of the European, both in India and in Europe. From such experiments we would be in a position to judge whether it was the effect of the climate or defect of the form of linseed cultivated that rendered the rejected stems of the Indian oil-yielding plant valueless as a source of flax.

At the late Colonial and Indian Exhibition, numerous inquiries were made as to whether India could not be induced to cultivate flax. The large, bold linseed was much admired, especially the white form, and several flax spinners solicited and obtained samples of the Indian seed, from a conviction that it was some defect in the cultivation that prevented the Indian plant from yielding a very superior flax. It was universally admitted that the time had now come for the English flax-spinners to seek a new source of supply, or some good substitute for flax.

While venturing to make the suggestion that experiments might be instituted on the subject of flax cultivation in India, we are fully aware that such experiments were performed from the beginning of the century down to about 1850. It is presumed, however, that the immense advances which have since taken place have prepared the way for the subject deserving renewed efforts. We are confident that just as with hemp so with flax, the remarkable progression of the jute trade hindered the establishment and growth of a flax industry. It is the opinion of most experts that a re-action has now set in, and that the demand for textiles of all kinds would justify a fresh effort being put forth. Moreover, it is presumed that the success of the wheat trade has abundantly demonstrated what may be done in India towards cultivating during the cold months crops peculiar to northern Europe. The experiments made with flax some half a century ago were chiefly in Bengal, whereas the more natural regions would appear to be some parts of the central provinces, of Bombay and the Punjab. That flax can be produced in India was demonstrated beyond all doubt (although it is probable that the fibre-yielding plant would be found to be of little or no value as a source of the oil-seed); indeed, so successful were the early experimenters, that in a letter dated November 22nd, 1841, the Government of India refused to afford any official assistance, because "the cultivation of flax can no longer be considered a doubtful experiment, since it appears from your (Agri-horticultural Society's) report to have proved in many instances successful; and where successful, to be very fairly profitable." In spite of this apparently hopeful position, the cultivation of flax was discontinued in India shortly after; but, be it observed, that this was the very period at which jute cultivation was making rapid strides.

MAOUTIA PUYA, Wedd.; URTICACEÆ.—*Poi*, Hind.

A shrub, with white leaves, found in the Himálaya from Garhwal eastward to Assam, and the Khásia Hills and Burma, chiefly in old cultivations and up to 4000 feet in altitude.

It yields a strong fibre of excellent quality, very much resembling rhea; this is made into fishing nets, net-bags, twine, and cloth. It seems highly probable that this plant could be more easily cultivated than the true rhea, and that the fibre would be found quite as serviceable.

A large bale of this fibre was shown at the Colonial and Indian Exhibition, and by experts pronounced identical with rhea. It now remains to be carefully ascertained in India whether there would be any advantage in cultivating this plant in place of *Bœhmeria nivea*. We can only repeat what we have said elsewhere, that every effort should be put forth in India to ascertain the peculiarities of every plant allied to rhea. In some respects the true rhea is too strong, and a rhea-like fibre a little inferior in point of quality, that could be more easily cultivated and more cheaply separated from the twigs, would in all probability prove a more profitable and more acceptable fibre than the rhea which has occupied, and justly occupied, the minds of experts for the last few years.

The specimen of this fibre exhibited was very inferior in many respects. It is introduced here, as presumably its rightful place, when normally prepared.

Not only was the specimen inferior in point of preparation (*vide* Analysis, Div. D), but it was found in the microscopic examination, impossible to isolate the ultimate fibre, by reason of its breaking up under the needles. Many of the fibres of the Urticaceæ show this tendency to brittleness; but with special attention to cultivation and the conditions of growth, these defects can in all probability be removed.

MARSDENIA TENACISSIMA, W. & A.; ASCLEPIADEÆ.—*Haba*, Bombay.

Filaments.—10-15 inches in length; 10-30 fibres in bundle.

Ultimate Fibre.—5-20 mm. in length.

A climbing shrub found in Kumaon, Oudh, Behar, Bengal, and Ava. It yields the silky fibre sometimes known as "Rajmahal hemp," one of the strongest and finest of all fibres, and yet at the present day one completely neglected. Dr. Roxburgh was the first to discover this plant, and to describe in the Flora of India the uses to which the fibre is put. The hill tribes of Bengal prepare a bow string with it which is said to last for years in all climates. Dr. Royle gave a little additional information, but for half a century nothing further has been learned regarding it. No experiments have as yet been made to ascertain whether or not this plant could be cultivated as a supply of fibre. Next to rhea, it must rank in point of fineness and durability, and we cannot urge its claims to the attention of Government in too strong terms. If it can be shown that the fibre could be cultivated at all, it might then become a question whether the *haba* or rhea could be produced cheapest.

VILLEBRUNEA APPENDICULATA, Wedd.; URTICACEÆ.—*Bun Rhea*, Ass.; *Lepic, Lipiah*, Nepal.

A small tree of the north-eastern Himálaya, Khásia hills, and Chittagong.

It yields an extremely valuable fibre of a rich brown colour, strong, and flexible; this is made into ropes, nets, and coarse cloth.

It is doubtful whether the samples shown as this fibre at the Colonial and Indian Exhibition were correctly so named. In India it holds a far higher reputation than the specimen we examined would seem to justify. Most of the *Urticaceæ* allied to *Bœhmeria* yield valuable fibres.

DIVISION B.—*Fibres of less textile value by reason of lignification and shortness of the ultimate fibre-cell.*

ABROMA AUGUSTA, Linn.; STERCULIACEÆ.—*Ulatkambal*, Beng.

Filaments.—Bundles of 10–50 fibres. Section fig. 15.

Ultimate Fibre.—Fig. 16. Slender, typical form; length 1·5–2 mm.

A small bush, widely spread, native or cultivated, throughout the hotter parts of India.

The bark of the twigs yields a much-valued fibre, which deserves to be more generally known. The plant is a perennial, stands coppicing, and yield three crops of fibre-twigs a year. This fibre might be used with advantage as a substitute for jute, which it resembles, but is much more durable.

ABUTILON ASIATICUM (AND INDICUM), G. Don; MALVACEÆ. —Country mallow; *Petari*, Beng.

Filaments.—Seen in section fig. 17. Very variable, usually from 10–50 fibres in bundles; strongly coherent.

Ultimate Fibre.—Fig. 18. Length, 2–4 mm.; ends taper to fine points. In section polygonal to ovoid, with large cavity.

These two plants are nearly allied botanically, and from an economic point of view they may be regarded as one and the same.

A. asiaticum, G. Don, is chiefly met with in Western India and Ceylon, while *A. indicum*, G. Don, is widely distributed throughout tropical India, to Prome, Pegu, and Ava (but not found in Malacca.)

The stems contain good fibres suitable for cordage. These exceedingly abundant wild plants deserve attention.

CORCHORUS CAPSULARIS (and OLITORIUS), Linn.: TILIACEÆ. —Jute; *Pát*, Beng.

This fibre being especially typical of the group and of lignified fibres generally, was more fully investigated. Plants of either species of normal growth, raised in this country by Dr. Watt, were cut down at the fruiting stage, and sections of the stem were cut at intervals throughout its length. It is, perhaps, worthy of mention that the plant of the former species attained a height of 5 feet (unbranched). The development of the fibre was traced in this way from its first origin in the cambium of the growing point to the highly differentiated triangular aggregates of the later growth. The course of development is shown in the sections (figs. 19, 20, 21): of these the first was taken at a point a few inches below the growing point, the second at about one-third of the length down, the third near the root. In the first the differentiation of the cambium, though not evident in the photograph, was perceptible to the eye, and very sharply brought out by means of reagents such as aniline sulphate, chlorine followed by sodium sulphite (red coloration), showing therefore that the chemical characteristics of this bast are manifested from its very origin, *that the lignocelluloses in fact are primary plant constituents.* Although we had previously found evidence of this in the uniformity of composition of the fibre-substance from root end to tip of the ordinary commercial fibre, the results of this histological examination of the stem affords important confirmation of this view, and throws light on the process of lignification generally.

In the portion of which fig. 20 is a representation, formation of new bast by differentiation of the cambium is actively proceeding. The bundles already formed are undergoing subdivision and further differentiation with thickening of the fibre or cell walls. In fig. 21 we have the final stage of development.

Filaments.—The fibre as found in commerce consists of the fibre bundles separated from the cortical parenchyma. The bundles contain from 6 to 20 fibres. Fig. 22 represents sections of the filaments highly magnified. The fibres are firmly coherent in the bundle, the cohesion taking the form of fusion of contiguous walls, the line of fusion being very apparent.

Ultimate Fibres.—These are seen in section, fig. 22; in the length, fig. 23. They are of the normal fusiform type, 1·5–3 mm. in length. In section, thick-walled and polygonal.

Reactions characteristic of the group: Brown with iodine; deep yellow with aniline sulphate; purple with phloroglucol and hydrochloric acid; a strong affinity for the basic colouring matters.

Mercerised fibre—Microscopic features.—Concentrated solutions of the alkalies have a remarkable action on fibres of this group. They resolve the bundles more or less completely, and cause the fibre wall to swell so as to almost obliterate the cavity (fig. 24). The filaments, in addition to being made finer, are much softened in texture, and develop a wavy outline, giving the fibre very much the appearance of wool.

This fibre is prepared by retting the stems of *Corchorus capsularis*, Linn., and *C. olitorius*, Linn., two species of closely allied plants. The former has a spherical fruit, flattened at the top; it is the species which yields the fibre in Central and East Bengal. The latter has an elongated fruit, and is the species cultivated in the vicinity of Calcutta. The genus *Corchorus* has representatives in all the warm, moist regions of the world—Asia, Africa, and America. Geographical evidence cannot therefore be resorted to in efforts to determine the ancestral home of the jute-yielding species. *C. olitorius* is the Jew's Mallow. It is cultivated in Egypt and in Syria as a vegetable, and in many other parts of the world. By some authors it is viewed as a native of Western India and of Kordofan. In Bengal, where both *C. olitorius* and *C. capsularis* are cultivated for the fibre, they do not appear to exist in a wild condition.

The first commercial mention of the word "jute" is in the customs returns of the exports for 1828. In that year 364 cwt., valued R620, of raw jute were exported to Europe. The manufacture of gunny-bags and cloth was then entirely in the hands of Indian peasants, but the trade must have been limited, since

there do not appear to have been any foreign exports in these jute manufactures. Jute mills were, however, early established in Dundee, and a large export trade in raw jute sprang into existence. Down to the year 1854 little or no effort was made to improve the Indian jute manufactures, but in that year the "Ishera Yarn Mills Company" was established near Serampore. Three years later the company, now known as the "Baranagore Jute Mills," was established, and in 1863–4 the "Gouripore Jute Factory" was founded. Factories sprang up rapidly in every direction around Calcutta. There are now 23 large jute mills at work in India, and in 1884–5 the exports of raw jute amounted to R4,66,13,684, and the exports of manufactured jute to R1,54,38,696. Expressing these figures at par, we have the startling fact that the value of the foreign trade in jute in 1828 was only 62*l.* sterling, but during 1885 it was 6,205,238*l.* In recent years the jute trade has not been in a very flourishing condition, over-production having caused a fall in prices. During this time, however, the exports of Indian manufactured jutes have been steadily improving, and the exports of raw jute apparently falling off. Little more than forty years ago the peasant hand-looms of India met the home and also the foreign demand for Indian-made gunny-bags, but the opening out of steam factories in India has not only absorbed this trade, but has greatly extended the foreign market. This is illustrated by the fact that in 1850–51 the exports of hand-loom manufactures were valued at 215,978*l.*; in 1884–5 they were only 51,882*l.* There were no European factories at work in India in 1850, so that the exports of manufactured jute which appear in the trade returns for that year must have been entirely hand-loom made. But even with 23 large factories at work, the foreign trade in raw jute is four times as valuable to India as her exports of manufactured jute. In estimating the total value of jute to India, care must be taken not to regard the quotations of imports and exports of jute and jute manufactures, declared as such, as indicating the actual extent of the trade. Leaving out of account the large quantity of jute used up annually by the people of India themselves for agricultural and internal trade purposes (home trade), an immense number of gunny-bags leave India in the foreign produce trade filled with wheat, rice, and other grains and seeds, and are therefore not included in the returns of exports of gunny-bags. Through the kindness of a Calcutta jute merchant the following figures have been procured for the total Bengal trade in jute manufactures during the year 1882. The commercial year does not correspond with the Government financial year, so that a slight difference exists between the figures compiled by merchants and those published by the Government of India. There were exported 41,523,607 power-loom made gunny-bags (this is given by Government as 41,156,766); but according to the Calcutta brokers there were sold in Calcutta over and above 77,519,164 gunny-bags. About one-half of these are shown in the Government reports of coasting and railway-borne trade to have been sent from Bengal to other provinces to be used in the home and foreign grain trade. Of the balance no record is preserved by Government in any form. These bags were of course used in the Bengal home and foreign grain trade. It should thus be carefully observed that the published figures of exports of manufactured jutes as such represent probably little more than one-third the actual trade in these bags. Mr. J. E. O'Conor, in his 'Review of the Trade of India,' for 1884–5, while speaking of the exports of manufactured jute, says, "the whole trade in jute manufactures" was valued at R1,54,38,696 (=1,543,869*l.*), but in his 'Annual Statement of Trade and Navigation,' he shows that power-loom gunny-bags to the value of R74,44,577 (over and above the foreign exports) were sent from Bengal to other provinces. If to this we add the value of the bags used up in Bengal itself, the whole value of the Bengal trade in jute manufactures cannot have been far short of 3 crores of rupees (3,000,000*l.*). Since 1882 the exports to foreign countries of jute manufactures have greatly improved; last year, for example, 77,841,776 gunny-bags left India, or, including hand-loom bags, 82,779,207 were exported, while nearly 40 millions were in addition sent to other provinces, and probably about the same number used up in Bengal itself.

The total value of the foreign jute trade during 1884–5 has been published as R6,24,15,687, and it is amusing to observe that raw jute is actually being imported into India, Arabia having sent raw jute to the value of R583. The imports of manufactured jutes were valued at R3,61,943, chiefly from Ceylon, Great Britain, and the Straits.

For special information in regard to recent developments of the application of jute, see Bull. Soc. Mulhouse, 1881.

GREWIA ASIATICA, Linn.; TILIACEÆ. — *Phálsa*, Hind. *Shukri*, Bengal.

A small tree cultivated throughout India, the bark is used in rope making, and much resembles the European bast (linden) fibre.

G. OPPOSITIFOLIA, Roxb.—*Biúl*, Hind.; *Pharwa*, Pb.

A small tree, wild in Northern India. The bark yields a fibre frequently used for cordage and in paper making.

From the very short length of the ultimate fibre, 1–1·5 mm. (fig. 25), and the inferior character of the specimen, it was not deemed worthy of further investigation.

HIBISCUS CANNABINUS, ESCULENTUS, FICULNEUS, SABDARIFFA, TILIACEUS, VITIFOLIUS, Linn.; MALVACEÆ.

The various species of Hibiscus (*infra*) yield fibres closely resembling jute, both in chemical and structural properties. The filaments, in section, are indistinguishable from those of jute. The ultimate fibres also. Of these the largest are found in the *H. cannabinus*, viz. 1·5–4 mm. (fig. 26), which confirms Dr. Watt's estimate of its relative superiority (*infra*).

HIBISCUS CANNABINUS, Linn.; MALVACEÆ.—Deccani hemp; hemp-leaved Hibiscus; *Ambárei*, Hind.; *Mesta-pát*, Beng.; *Garnikura*, Sans.

A small herbaceous shrub, with prickly stems, apparently wild, east of the Northern Gháts. Largely cultivated, especially in the North-west Provinces and the Panjáb, for its fibre, which is stronger though not so good as Sunn (*Crotalaria juncea*). In Sind this is considered the best fibre for nets and ropes. It is the chief fibre used in the manufacture of paper in the Dacca district, Bengal. It is also employed for this purpose in the Madras Presidency.

A very interesting fibre, and deserves more attention. It is sometimes met with as an "adulterant" of jute.

H. ESCULENTUS, Linn.—The edible *Hibiscus*; *Ochro* of West Indies; *Gombo*, Fr.; *Bhindi*, Hind.

A herbaceous annual bush, naturalised in all tropical countries; only met with in a cultivated state in India.

The bark yields a strong useful fibre, deserving of more attention, especially by paper-makers. The plant is extensively cultivated as a vegetable, and the fibre might therefore be procured at a reasonable rate.

H. FICULNEUS, Linn.—*Kapasiya*, N.-W. P.

A native, most probably, of the Southern Provinces; naturalised in the Panjáb, Bengal, the Circars, and the Concan. A small herbaceous and annual bush, which should be sown at the beginning of the rains.

Like most other members of the Malvaceæ, this yields a valuable fibre. Roxburgh says: "In none have I found so large a quantity, equally beautiful, long, glossy, white, fine and strong as in this. To these properties may be added the luxuriant growth and habit of the plant, rendering it an object of every care and attention, at least until the real worth of the material is fairly ascertained." Like many other of Roxburgh's valuable economic discoveries, this has remained for nearly a century without having been taken any advantage of. The immense success of jute has obscured not a few fibres, which, although not so easily and cheaply separated, would be far more valuable were they to be substituted for many of the purposes to which jute is now put. Of these may be mentioned the fibres of the various species of *Hibiscus, Abroma, Abutilon,* and *Sida.*

HIBISCUS SABDARIFFA, Linn.—The Rozelle fibre.

A small bush, cultivated in many parts of India. The stems yield a good, strong, silky fibre. This is obtained by retting the twigs when in flower.

H. TILIACEUS, Linn.—The *Bola* or *Chelwa* of the coast of Bengal.

This large bush is exceedingly plentiful on the coast; its abundance, and the ease with which it might be still further extended over tracts of country where little else will grow, being powerful reasons for the utilisation of the plant being carefully considered. It yields a useful and strong jute-like fibre, extensively used for cordage. It is said to gain in strength when tarred.

The fibre is readily separated from the green or unsteeped branches, the work of preparation being less tedious than with the other fibre-yielding plants of the genus. It appears to be well adapted for making ropes, mats, and paper.

H. VITIFOLIUS, Linn.—*Bun-kapas,* Beng.

A common bush throughout India. The bark yields a strong silvery fibre.

Considerable ambiguity is caused through the various species of *Hibiscus* being classed together, and even the fibre of Sunn, or brown hemp, spoken of as if it were a *Hibiscus.* This has doubtless come into existence from the fact that in Saharanpur, and many other parts of Northern India, the fibre of *H. cannabinus* is called *San* or *Saní,* a name which it seems desirable to restrict to *Crotalaria.* Of the fibres derived from the genus *Hibiscus,* that from *H. cannabinus* is by a long way the best and most extensively cultivated. Were a demand to arise for this fibre, a large trade might easily enough be organised from Chutia Nagpur, the Central Provinces and the Panjáb.

HIBISCUS ELATUS, Sw.—*Cuba* bast.

This fibre, the West Indian Mahoe, is cited in the analytical table, for purposes of comparison, by those to whom the fibre is of possible interest, with Indian fibres. We take this opportunity of referring to the report upon the miscellaneous fibres exhibited in the Colonial sections, the investigations for which were worked side by side with those of the present report. Those specially interested in the subject may find some interest in comparing the results of both.

Filaments.—Resemble *Hibiscus* fibre; pale greenish-yellow colour; somewhat encrusted.

Ultimate fibre.—Fig. 27. Length, 1–1·5 mm.

PAVONIA ZEYLANICA, Cav.; MALVACEÆ.—*Bala,* Sans.

A much-branched shrub, common in the North-west Provinces, Sind, the Western Peninsula and Ceylon. It yields a fibre of excellent quality. *P. odorata* affords a similar fibre, and both these plants deserve to be more carefully cultivated and their fibres tested.

The short length of the ultimate fibre (fig. 28), viz. 1–1·5, places this fibre low in the scale of value.

SIDA RHOMBIFOLIA, Linn.; MALVACEÆ.—*Swet-berela,* Beng.

Filaments.—Fig. 29. Similar to jute in all structural points.

Ultimate fibre.—Fig. 30. Length, 1·5–2 mm. Similar to jute.

Reactions.—The same as those of jute.

Although closely similar to jute in structure and general chemical characteristics, it is in appearance a superior fibre: it is softer to the touch, and in all respects more uniform. This superiority, moreover, is confirmed by comparative chemical investigation, to show which we reproduce side by side analytical numbers obtained for the two fibres.

	Jute.	Sida.
Moisture	10·3	10·7
Ash	1·2	0·6
Hydrogen (*a*)	15·0	6·6
" (*b*)	18·0	12·2
Cellulose	75·0	83·0
Mercerising	16·0	6·6
Nitration	125·0	137·0
Acid purification	1·0	0·3
Carbon percentage	46·5	45·0

In the relatively high percentage of cellulose we have the most important factor of superiority. It is interesting to note the correlations with this cardinal point of difference of all the other quantities determined. This fibre is undoubtedly worthy of extended investigation by practical men, on which point Dr. Watt has already expressed himself in public (*infra*).

The plant yielding this fibre is a small gregarious bush, abundant in many parts of India, especially so in Bengal, but nowhere as yet cultivated.

"A beautiful silvery white fibre is obtained from the above-named plant—a member of the mallow family. Botanically, *Sida* may be said to be allied to jute, and the fibre it affords in many respects resembles jute. It may be grown on the same fields, and by the same cultivators. It can therefore be produced at about the same price, for the fibre may be separated from the stems by the same simple process, namely, by retting and washing in water. The only factor that might conduce to make it more expensive than jute is the fact that in its wild state it does not attain the same length of stem as the cultivated jute; but *Sida* has not been cultivated as yet, and there is no knowing but that it may even exceed jute in its yield of fibre per acre. It may be accepted, however, that *Sida* fibre is, like jute, a cheap fibre, and one that might be produced with great ease in immense quantities, the supply being as constant as that of jute. Its claims for superiority over jute are very considerable. The fibre is not half as coarse as jute, and it is of a much purer quality,

and can therefore be spun into finer yarns than jute, and thus come into textile purposes which jute has totally failed to reach. It can take colour with great ease. In fact, *Sida* fibre has been much admired by all the manufacturers who have examined it. It is now being experimented with on both flax and jute machinery, and I am hopeful that, as one of the tangible outcomes of the late exhibition, this fibre will, in a very few years, come to hold a distinct place amongst the fibres exported from India."—(*Watt, 'Journal Society of Arts,'* 1887.)

URENA LOBATA, Linn.; MALVACEÆ.—*Bun-ochra*, Beng.

Filaments.—Indistinguishable in section from *Hibiscus* fibre.

Ultimate fibres.—Length, 1·5–2·0 mm.

A common wild shrub met with all over India, especially in the hotter regions.

The bark abounds in a strong useful fibre, which the natives consider suitable for sacking and twine.

DIVISION C.—*Monocotyledonous Fibres.*

We have not in the present paper attempted to examine chemically and microscopically the properties of all the monocotyledonous textile fibres of India. Most of these of any value are obtained from introduced plants and are already well known. The following are enumerated more by way of making the present brief review include all the fibres of India which have a recognised position along with those which seem likely to be better known in the future.

AGAVE AMERICANA, Linn.; AMARYLLIDEÆ.—American aloe; vegetable silk.

Ultimate Fibre.—Length, 2–6 mm.

A native of America but naturalised in many parts of India. The leaves and the root yield an excellent fibre.

A. VIVIPARA, L.—The bastard aloe.

This is altogether a much less robust plant than *A. americana*, and produces viviparous buds upon an erect stem. The leaves are less fleshy, and erect instead of reflexed. The flowering stem is less than half the height of that of *A. americana*, and much thinner and red-coloured.

Either or both of these plants are now widely cultivated in India, especially as protecting hedges to the railways. Experimental cultivation as a fibre supply has also shown that this may be remunerative. All that is necessary at the present day is a uniform and sufficiently extensive demand to warrant the undertaking to make a trade of preparing the fibre.

ANANASSA SATIVA, Linn.; BROMELIACEÆ.—The pine-apple; *Ananas*, Hind.

Ultimate Fibre.—Length, 2–5 mm.

This and all other members of the *Bromeliaceæ*, now met with in India, were introduced from America.

The leaves, which require to be steeped in water for eighteen days, yield a beautiful fibre, which, but for the difficulty of extraction, would be largely employed. The fibre is used in India for the manufacture of a thread employed for threading beads, &c., in necklaces. Since its introduction into India, the pine-apple has taken hold of many extensive tracts of country, especially in Burma and the Straits. It has become an abundant and in many places an objectionable weed. Should therefore a demand arise for this beautiful fibre, as indeed there is reason for anticipating, India might fairly be expected to afford an extensive supply.

CARYOTA URENS, Linn.; PALMÆ.—Vern. Names. *Salopa*, Uriya; *Simong*, Leptcha; *Bara flawar*, Assam; *Bherlá-máda*, Mahr; *Conda-panna*, Tamil; *Minbaw*, Burmese; and the *Kittúl* of Ceylon.

A beautiful palm with smooth stems, met with in the forests of western and eastern moist zones.

The long cord-like threads found near the base of the leaves and embracing the stem, form the *kittúl* fibre, now so extensively employed in Europe in the brush trade. This has hitherto been entirely obtained from Ceylon, the Indian people being apparently ignorant of the fact that it possesses any commercial value. The stronger fibro-vascular bundles extracted from the stem, were shown at the Exhibition, and thought to have a chance to come into use as a substitute for whalebone in the manufacture of corsets.

MUSA PARADISIACA, Linn.; SCITAMINEÆ.—The Plantain; *Kela*, Hind., Bomb.; *Kela*, Beng.

Ultimate Fibre.—Length, 2–4 mm.

Various species of plantain are extensively cultivated throughout India, and several wild forms occur in the sub-tropical forest.

A beautiful fibre is obtained from the stem of the Indian plantain, though inferior to that of the Manilla-hemp. Attention has of late years been attracted to the plantain as a raw material for paper-making. It seems probable that a good future is before the paper industry of India, and that amongst many other fibres the thousands of plantain stems, which by the natives are annually thrown away as useless, may yet come to be used for this manufacture. The chief difficulties consist in the low yield of fibre and in the fact that the cultivated plantain stems would have to be collected over a wide area, since it would scarcely pay to cultivate the plant exclusively as a paper material. The wild plantains, on the other hand, frequent the inaccessible recesses of the forests and the question of freight to the paper mill would all but prove fatal.

Musa textilis affords the Manilla-hemp of commerce. Large quantities of this fibre are annually imported by Messrs. Harton & Co., and other Indian rope manufacturers; samples of their ropes, made by this fibre, were shown on the "Rope Trophy" at the Colonial and Indian Exhibition. Attempts to introduce this plant into the plains of India have been made but with little success. An effort is now, however, being put forth to acclimatise the plant in the Andaman Islands, and the experiment so far seems successful.

SANSEVIERIA ZEYLANICA, Willd.; LILIACEÆ.—The Bow-string hemp.

Ultimate Fibre.—Length, 1·5–3 mm.

A stemless bush with a rosette of leaves; common on the coast of South India.

From the succulent leaves is extracted a beautiful, soft, silky fibre, held in high esteem by the natives on account of its elasticity and its consequent suitableness for bow-strings. The fibre is much valued for the ropes employed in deep-sea dredgings. It makes a very superior paper, but except for very special qualities, is too expensive for the paper-maker.

YUCCA GLORIOSA, Linn.; LILIACEÆ. — Adam's needle; the silky grass fibre.

Ultimate Fibre.—Length, 1–5 mm.

A native of America from Carolina to Mexico and Texas. Introduced into India, met with in gardens in Bengal, occasionally naturalised in the Madras Presidency.

The fibre which it yields resembles in many respects that of the *Agave*, and is applicable to similar purposes. There are several species, all of which yield excellent fibres; but *Y. gloriosa* is the principal one and may be taken as the type of the others. The root is said to be employed as a substitute for soap.

Division D.—*Paper and Rope-making Fibres.*

The art of paper-making in India dates from the great Emperor Akbar, and was first practised in Kashmír. Rapidly it spread all over India, displacing the birch-bark used by the hill tribes and the palm-leaves by the people of the plains. It is probable, however, that the art of Nepal paper-making came from China to the inhabitants of the Eastern Himálaya long anterior to the introduction of the paper industry by Akbar. Even at the present day the paper-making of the natives of India is very much like their glass-blowing, since it largely consists in re-making from paper-waste.

In a country teeming with fibre-plants, it is a surprising fact that the question of an Indian paper-fibre should still be under consideration. European writers seem always to forget, however, the immense size of the continent of India; while a few hundred miles are of little consideration in many Indian questions, the proportional railway freight upon a bulky article often becomes prohibitive even to industries with a larger margin of profit than paper-making. To cultivate fibre specially for paper has many drawbacks; one only need be mentioned—the cost of land near commercial centres. A paper fibre must be, like esparto, fit almost for immediate immersion in the vats, since paper-making can never pay for the separation of fibre, even where land can be got at a merely nominal rent. Perhaps no fibre known to commerce can compete with jute in point of cheapness, yet the paper-maker can afford to purchase jute waste and jute cuttings only, so that but for the demand for an altogether different purpose, the paper-maker could never procure jute. The two most important indigenous paper-fibres, in India, are *munj* grass and *bhabar* grass. These are now being largely used by our Indian paper-mills, the supply at a remunerative price being the chief obstacle. The roots and lower stems of rice

have been suggested as a paper-fibre, and if established, that this material would be worth the trouble of collecting, the supply might be practically unlimited, but it is doubtful whether the paper-maker could pay sufficient to cover freight and expense of collection. It has been demonstrated that bamboo affords excellent paper, but it is feared practical difficulties exist which for the present at least, dispel the hopes once entertained of the immense tracts of bamboo forest becoming of commercial value.

With esparto at present selling in England at 4*l.* a ton, there can be little or no chance for the fibres of India being exported to Europe, to any large extent at least, as paper materials. Indeed, the European manufacturer has to complain far more of a depreciation in price and demand rather than in any scarcity of raw material. It is curious that in the returns of the exports from India of rags and other materials, almost the entire amount (valued at 37,053*l.*) appears to have been sent to the United States of America, a great country which might naturally be expected to be independent of India, in this direction at least.

From what we have said, it will be seen that our remarks regarding Indian paper-fibres are of interest mainly to India herself. The future of the Indian paper-mills hinges on their ability to meet the Indian market, and their power to lessen not merely the government but the commercial imports of European made papers. By far the best materials in India are of course cotton rags, waste jute, and old ropes of sunn-hemp, together with *bhabar* and *munj* grass.

In one jail on the North-west Himalaya, paper is made from the bast of *Desmodium tiliæfolium*, and throughout the entire length of the Himálaya, daphne bark is collected for local paper manufacture. It seems to be an accepted idea in India, that one day the *Broussonetia* will be cultivated as a hedge plant throughout the greater part of the plains of India, and thus become the Indian paper-fibre of the future. If it will ever pay to cultivate any paper-fibre this may confidently be viewed as certainly the most hopeful.

There are, however, many fibres that would appear to repay careful investigation, and our remarks under a few of the following may therefore be of some practical value to the Indian manufacturer. We have used an asterisk to indicate the fibres that we regard as of too superior quality to be employed for paper. These may accordingly be viewed as rope-fibres.

The imports and exports of ropes and cordage to and from India last year were valued at 70,580*l.*, but this does not of course include the very considerable Indian trade in Indian made ropes. It is surprising that with the exception of coir or cocoa-nut fibre and of sunn-hemp, no other Indian fibre is used to any very great extent. A very considerable import trade exists in Manilla hemp (the long silvery fibre from *Musa textilis*), for the Indian rope manufactures. At the late Colonial and Indian Exhibition, Messrs. Harton and Co., of Calcutta, exhibited a very attractive trophy of ropes, in which the frame-work consisted of Manilla hemp and coir hawsers. Efforts to introduce the Manilla hemp plant into India have practically failed, but it is surprising that none of the numerous indigenous fibres treated of in this report have been found serviceable for rope purposes. Indeed it would seem that this is far more a consequence of trade prejudice than of any want of good rope fibres in India. It would appear that colour, cleanness and general appearance, have a greater influence in the rope market than ascertained strength and durability.

*ANONA RETICULATA, Linn.; ANONACEÆ.—Bullock's heart; *Nona*, Beng.

Ultimate Fibre.—Length, 1–2 mm.

A small tree, common everywhere; by some authors regarded as wild in some districts, but it is chiefly met with in cultivation.

A good fibre is prepared from the bark of the young twigs.

*A. SQUAMOSA, Linn.—Custard apple; *Saripha*, Hind.

A small tree, the sweet-sop of the West Indies, naturalised in Bengal and the North-west Provinces.

An inferior quality of fibre may be prepared from the twigs of this tree.

It is improbable that either of the above fibres will ever come to have more than a local interest.

BAMBOO.

Ultimate Fibre.—Length, 2–4 mm.

Mr. Routledge, in his pamphlet on 'Bamboo as a Paper-making Material,' makes the following remarks:—"Of all the fibre-yielding plants known to botanical science, there is not one so well calculated to meet the pressing requirements of the paper trade as 'bamboo,' both as regards facility and economy of production, as well as the quality of the 'paper stock' which can be manufactured therefrom." While this is doubtless correct, there are practical difficulties which render it extremely improbable that bamboo will ever come into use as a paper material. The difficulty of getting a continuous supply of young shoots without injuring, if not killing, the clumps, after two or three years, the heavy charges likely to be incurred in conveying the material from malarious jungles to the mill, and the fact of the scales and young stems being covered with hairs which cannot be removed, render the bamboo practically unsuitable for paper-making. Experiments recently conducted have proved that a clump of bamboo is killed after a very few years if a large percentage of the shoots be systematically removed. The natives of India, and of China, however, do make paper from bamboo, and do not appear to regard it as absolutely necessary to use the young shoots only.

The following are the principal bamboos of India that may come to be used in the manufacture of paper:—

BAMBUSA ARUNDINACEA.—Burma.

B. BALCOOA.—Bengal and Assam.

B. BRANDISII.—Burma.

B. TULDA.—Bengal.

B. VULGARIS.—Throughout India.

DENDROCALAMUS HAMILTONII.—Bengal and Assam.

D. STRICTUS.—The male bamboo on the lower hills throughout India.

BAUHINIA VAHLII, W. and A.; LEGUMINOSÆ.—*Maljan*, *malu*, Hind.; *Chehur*, Beng.; *Adda*, Tam.; *Sihar*, C.P.

Ultimate Fibre.—Length, 2–3 mm.

This is one of the most extensive, as it is one of the most abundant and most useful of Indian climbers. It is found all along the lower Himálaya from the Chenab eastward, in North and Central India, and Tenasserim.

It abounds throughout all the warm lower mountainous tracts, being most abundant in the mountainous forest of the great table-land of India, and crossing the Gangetic basin it occurs again in all the forests which skirt the foot of the Himálaya. "Mr. Routledge, of Sunderland, was, I believe, the first person who drew prominent attention to the fibre derived from this plant. Long before even Mr. Routledge's attention was directed to it, however, the late Dr. Forbes Royle spoke highly of it under its vernacular name, and specimens were exhibited at the Great International Exhibition of 1851. The fibre is universally used by the natives of India for the purpose of rope-making, and it stands high in their esteem. Mr. Routledge has urged its use in the paper trade; but, although the plant is sufficiently abundant to warrant the idea that it might even pay to be thrown into the paper-maker's vat, it seems to possess such merits as a possible textile fibre, that it is more likely to find a much higher place than Mr. Routledge designed for it. The *malu* fibre may be gathered in immense lengths, for the plant is one of those gigantic climbers which, by means of its tendrils, extends its long arms from tree to tree, binding the forest into great clumps. It is, indeed, a source of the greatest annoyance to the forester, for it not only injures his trees, but has such a vitality that it is next to impossible to exterminate the plant, and a few months after it has been cut to the ground, its long, elegant pendant boughs, laden with its great clusters of white flowers, are seen waving in defiance from the topmost branches of the trees. A very large and practically inexhaustible supply might be drawn from the forests of India, at the same time I have no confidence in a large industry depending upon a wild plant. The wide area over which it would have to be collected, and the complete control which the owners of the forests could exercise over the buyer, would be dangerous to success. As a practical experiment, a tract of country, say twenty miles, of the comparatively useless stony hill-sides would have to be purchased and systematically planted. A forest is not necessary for the plants to climb on; they would trail over the ground and form with each other great clumps. From such a plantation a nucleus of supply could be drawn and depended upon, which would have a good moral effect upon the persons bringing to the planter supplies from the wild source. Thus it would be possible to pave the way for a constant supply, and if this can but be secured, the fibre possesses in itself such high merit that it will soon make itself known in the textile world. It is one of the few vegetable fibres that will stand to be dyed,

bleached, and worked up along with wool, a property which speaks volumes in itself."—(*Watt, 'Journal Society of Arts'*).

Broussonetia papyrifera, Vent.; Urticaceæ.—The Paper Mulberry tree.

Ultimate Fibre.—Length, 6–20 mm.

A small tree, said to be wild in the Martaban hills; more peculiarly a native of Japan, China, Polynesia, and Siam.

The Japanese make paper from the bark, and the Burmese construct their curious papier-mâché school slates (*parabaik*) from it. The Tapa cloth of the South Sea Islands is made from *Broussonetia*, and so also is the Karen paper mulberry cloth.

Numerous experiments, both in Burma, Bengal, and the North-west Provinces, have been carried out with the view of discovering whether it was possible to extend the cultivation of this most useful plant. Mr. Duthie, of Saharanpur Botanic Gardens, reports, "Should it ever be under consideration to cultivate this plant on a large scale, I can safely say that there need be no anxiety as to its not thriving to perfection in this climate. It is easily cultivated both by seed and from cuttings." Dr. King, of the Calcutta Botanic Gardens, also reports, "This climate appears to be very suitable for the paper mulberry. Not a single seedling that germinated has died, either from the effects of cold, damp, or in the process of transplanting."

This plant certainly deserves to be more carefully investigated than hitherto. The experiments which have been made have established beyond all possible doubt that it can be cultivated throughout the hotter moist parts of India. The development of the bast in the plant is very considerable, and as the fibre felts into an exceptionally strong paper it is possible that this substance would meet special purposes and thus pay to be exported. Mr. Routledge says of it, "I must admit this fibre is even superior to bamboo. It requires very little chemicals and gives a good yield, 62·5 per cent. in the grey (i.e. merely boiled) and 58 per cent. bleached."

To make the Burmese *parabaik* or black-board, like cardboard, the substance is pounded into a pulp with water and half its weight of lime. This mixture, with a sufficiency of water added to it, is then boiled until nearly all the water has evaporated and the mass reduced to a soft pulp. It is next first person who drew prominent attention to the fibre derived from this plant. Long before even Mr. Routledge's attention was directed to it, however, the late Dr. Forbes Royle spoke highly of it under its vernacular name, and specimens were exhibited at the Great International Exhibition of 1851. The fibre is universally used by the natives of India for the purpose of rope-making, and it stands high in their esteem. Mr. Routledge has urged its use in the paper trade; but, although the plant is sufficiently abundant to warrant the idea that it might even pay to be thrown into the paper-maker's vat, it seems to possess such merits as a possible textile fibre, that it is more likely to find a much higher place than Mr. Routledge designed for it. The *malu* fibre may be gathered in immense lengths, for the plant is one of those gigantic climbers which, by means of its tendrils, extends its long arms from tree to tree, binding the forest into great clumps. It is, indeed, a source of the greatest annoyance to the forester, for it not only injures his trees, but has such a vitality that it is next to impossible to exterminate the plant, and a few months after it has been cut to the ground, its long, elegant pendant boughs, laden with its great clusters of white flowers, are seen waving in defiance from the topmost branches of the trees. A very large and practically inexhaustible supply might be drawn from the forests of India, at the same time I have no confidence in a large industry depending upon a wild plant. The wide area over which it would have to be collected, and the complete control which the owners of the forests could exercise over the buyer, would be dangerous to success. As a practical experiment, a tract of country, say twenty miles, of the comparatively useless stony hill-sides would have to be purchased and systematically planted. A forest is not necessary for the plants to climb on; they would trail over the ground and form with each other great clumps. From such a plantation a nucleus of supply could be drawn and depended upon, which would have a good moral effect upon the persons bringing to the planter supplies from the wild source. Thus it would be possible to pave the way for a constant supply, and if this can but be secured, the fibre possesses in itself such high merit that it will soon make itself known in the textile world. It is one of the few vegetable fibres that will stand to be dyed,

bleached, and worked up along with wool, a property which speaks volumes in itself."—(*Watt, 'Journal Society of Arts'*).

BROUSSONETIA PAPYRIFERA, Vent.; URTICACEÆ.—The Paper Mulberry tree.

Ultimate Fibre.—Length, 6–20 mm.

A small tree, said to be wild in the Martaban hills; more peculiarly a native of Japan, China, Polynesia, and Siam.

The Japanese make paper from the bark, and the Burmese construct their curious papier-mâché school slates (*parabaik*) from it. The Tapa cloth of the South Sea Islands is made from *Broussonetia*, and so also is the Karen paper mulberry cloth.

Numerous experiments, both in Burma, Bengal, and the North-west Provinces, have been carried out with the view of discovering whether it was possible to extend the cultivation of this most useful plant. Mr. Duthie, of Saharanpur Botanic Gardens, reports, "Should it ever be under consideration to cultivate this plant on a large scale, I can safely say that there need be no anxiety as to its not thriving to perfection in this climate. It is easily cultivated both by seed and from cuttings." Dr. King, of the Calcutta Botanic Gardens, also reports, "This climate appears to be very suitable for the paper mulberry. Not a single seedling that germinated has died, either from the effects of cold, damp, or in the process of transplanting."

This plant certainly deserves to be more carefully investigated than hitherto. The experiments which have been made have established beyond all possible doubt that it can be cultivated throughout the hotter moist parts of India. The development of the bast in the plant is very considerable, and as the fibre felts into an exceptionally strong paper it is possible that this substance would meet special purposes and thus pay to be exported. Mr. Routledge says of it, "I must admit this fibre is even superior to bamboo. It requires very little chemicals and gives a good yield, 62·5 per cent. in the grey (i.e. merely boiled) and 58 per cent. bleached."

To make the Burmese *parabaik* or black-board, like card-board, the substance is pounded into a pulp with water and half its weight of lime. This mixture, with a sufficiency of water added to it, is then boiled until nearly all the water has evaporated and the mass reduced to a soft pulp. It is next pounded, and boiling water added until reduced to a consistence suitable to be thrown upon the frame. The edges are then trimmed and the blocks air-dried, being afterwards polished and varnished.

*Cocos nucifera, Linn.; Palmæ.—The Coir or Cocoanut Fibre; *Narikel*, Beng.; *Tenga*, Tam.

A pinnate-leaved palm, cultivated and wild throughout tropical India, particularly near the sea-coast.

The thick, fibrous pericarp (husk) yields the valuable coir fibre of commerce. A fibre from the leaf-stalks is also prepared, but compared to the coir it is unimportant. The foreign trade in unmanufactured coir for the year 1884–85 was valued at R1,20,799 and of manufactured at R21,35,996.

*Debregeasia bicolor, Wedd; Urticaceæ.

A large shrub of the Salt Range and of the North-west Himálaya, ascending to altitude 5000 feet.

The fibre is made into twine and ropes. It is very strong, and may be viewed as allied to rhea.

Dendrocalamus strictus, Nees.; Gramineæ.—The Male Bamboo; *Ilyinwa*, Burmese.

Ultimate Fibre.—Length, 1·5–3·5 mm.

A common bamboo met with on the lower hills of India, ascending to 6000 feet altitude.

The stems are used by the natives for roofing, wattle and basket-work. They are also made into fishing-rods, spear-handles, &c. This is perhaps one of the best bamboos for the paper-maker's purpose.

*Edgworthia Gardneri, Meisn.; Thymelæaceæ.

Ultimate Fibre.—Length, 3–5 mm.

A large elegant bush, almost leafless when covered with its clusters of yellow, sweet-scented flowers. Found along the Himálaya from Nepal to Sikkim and Bhután and Manipur.

This plant is closely allied to the Daphne, and a strong fibre is obtained from its long straight and partly-branched twigs.

Eriodendron anfractuosum, DC.; Malvaceæ.—The White Cotton tree; *Safed simal*, Hind.

Ultimate Fibre.—Length, 1–2 mm.

A tall, deciduous tree of India and Burma, found throughout the hotter parts.

This yields the *kapok* fibre of Java recently introduced to European commerce by the Dutch. This is a soft silky floss, obtained from the seeds. In South Canara a fibre is also extracted from the stem which is said to be suitable for the manufacture of paper.

*Ficus bengalensis, Linn.; Urticaceæ.—The Banyan tree; *Bar*, Hind.; *Bat*, Beng.

Ultimate Fibre.—Length, 1–3 mm.

One of the most characteristic of Indian trees.

A coarse rope is made from the bast and from the aërial roots, and paper is also reported to have been formerly largely prepared in Assam from the bast.

The basts of other species of *ficus* are used in many parts of India in the construction of strong useful ropes.

*Guazuma tomentosa, Kunth; Sterculiaceæ.—The Bastard cedar.

Ultimate Fibre.—Length, 1–2 mm.

A tree stellately hairy upon the young twigs. Perhaps only introduced into India.

It yields a fibre which is very little known, but would perhaps prove useful as a rope fibre if the plant were to be cultivated for that purpose.

*Hardwickia binata, Roxb.; Leguminosæ.—*Aojan*, Hind.; *Acha*, Tam.

Ultimate Fibre.—Length, 1–2 mm.

A large, deciduous tree of the dry forests of South and Central India.

The bast yields a strong and valuable fibre, much used for ropes by the inhabitants of the forests where it abounds.

*Helicteres Isora, Linn.; Sterculiaceæ.—*Maror-phal, kapasi, bhandu*, Hind.; *Antmora*, Beng.

Ultimate Fibre.—Length, 1–2 mm.

A large, dense shrub of the tropical or sub-Himálayan regions; from the Panjáb to Bengal, South and Central India, and Burma.

The fibre extracted from the bast is strong, white, and very useful for cordage, rough sacking, and canvas.

Kydia calycina, Roxb.; Malvaceæ.—*Pola, púla, potari*, Hind.; *Barranga, bhoti*, C.P.; *Váranga*, Bomb.; *Kopasia*, Uriya.

Ultimate Fibre.—Length, 1–3 mm.

A small tree common in the forests of all parts of India and Burma, except the more arid regions.

The inner bark yields a strong useful fibre made into ropes by the natives of India, but might be used in paper-making.

*LAPORTEA CRENULATA, Gaudich.; URTICACEÆ.

Ultimate Fibre.—Length, 8–16 mm.

A tree of Sikkim, Assam, Eastern Bengal, the West Coast, Ceylon, and Burma.

This yields a good fibre, which can be made into ropes and coarse cloth. It is more or less allied to rhea, and like that fibre is very strong.

*MALACHRA CAPITATA, L.; MALVACEÆ.—Vern. *Ran-bhendi*, Bombay.

A common plant throughout the hotter parts of India, from the North-west provinces to the Carnatic. It thrives in Bengal and Bombay when cultivated, and in many respects resembles the jute plant; while it frequents marshy ground, it does not require the same amount of moisture, or rather submersion, essential for jute cultivation. In the 'Flora of British India' it is stated this plant was most probably introduced into India from South America.

During 1878–79 considerable attention was directed to this fibre, in consequence of a letter written by Dr. Gray on the subject. The Government of India directed the Bombay Government to institute experiments with the fibre, as it was admitted a necessity existed in the Western Presidency for some cheap fibre which might compete with the jute of Bengal in the manufacture of cheap sacking for the grain trade. The experiments were so far successful. It was found that a fibre seven or eight feet long might be prepared, and that a *bigha* (1600 square yards) would produce 560 lbs. fibre. The average yield of jute per *bigha* is about five maunds, or say 420 lbs., but it is often as low as two maunds, or may rise to 10 or even 12. The *ran-bhendi* was found not to exhaust the soil, and to ripen its fibre in four months. The fibre, while pronounced harsh, was admitted to have a superior lustre to jute, but to have a defect in not breaking with the forked ends characteristic of jute.

It may be concluded, however, that in every point it was established that *Malachra* could be employed as a substitute for jute, but through pressure of other more profitable commercial

pursuits in Bombay, the subject was allowed to d[illegible]uced, but it planted by the much finer, softer and more silvery fibre [illegible] to there is every chance, however, that it will be introduced and employed in manufacturing the Bombay sacks required for the Western grain trade.

MELIA AZADIRACHTA, Linn.; MELIACEÆ.—The Neem or Margosa tree.

Ultimate Fibre.—Length, 1–2 mm.

A common tree, planted by road-sides all over India and Burma.

The bark yields a fibre commonly employed in the manufacture (locally) of ropes. It would never pay, however, to extract this fibre for commercial purposes, since the trees take years to grow, and would be killed by a wholesale process of decortication.

PARKINSONIA ACULEATA, Linn.; LEGUMINOSÆ.

Ultimate Fibre.—Length, 1–2 mm.

An introduced shrub, now almost naturalised in India, especially in the arid zones, where it grows as a hedge plant.

It yields a short, somewhat brittle white fibre, considered wanting in strength, which might be used for paper-making locally when better fibres were not obtainable.

POLLINIA ERIOPODA, Trim. (formerly known as ERIOPHORUM COMOSUM), Wall.; GRAMINEÆ.—Babar or Baboi Grass.

A grass, met with throughout the central table-land of India, from Bengal to Madras, and the North-west Provinces and Central India; in some parts of the country extremely abund[illegible].

As a paper material, this grass has been reported as little inferior to esparto, and the paper made from it as of good quality. The great drawback to the fibre is that it would not pay to cultivate the grass purely for the purpose of a paper supply, and the wild plant has to be collected over wide and distant areas. The question of freight is in India one of most serious consequence, for if a bulky substance has to be carried for great distances by railway the price of the article is enhanced to a prohibitive extent.

The Indian paper mills are largely using *bhabar* grass, and samples of paper and paper-stuff made of it were shown at

A sm... ...nd Indian Exhibition, by the Bally Paper

The fibre is also extensively made into strings, cords, and ropes. They have the reputation of lasting under water.

SACCHARUM SARA, Roxb.; GRAMINEÆ.—Munj or Sara Grass.

This grass is very common in North India, especially in the Panjáb.

It is useful in the manufacture of strong ropes, strings, mats, and paper. For ropes it is much valued on account of its elasticity and strength, and a power of resisting moisture, common to few other fibres. The flower-heads and sheaths of this plant constitute one of the best paper grass materials in India. For this purpose it is largely used by the Upper India Paper Mills, near Lucknow. The *bán-múnj* is the flower sheath from which the natives prepare a fine thread.

SESBANIA ACULEATA, Pers.; LEGUMINOSÆ.—*Dhanicha*, Beng.

Ultimate Fibre.—Length, 2-4 mm.

This bush is found in Bengal and South India.

A strong fibre is extracted from its stalks, and made into ropes and fishing nets. This fibre is much valued because of its high power of endurance under water. It is superior to jute in strength and durability, and is best suited for the manufacture of cordage, for which purpose it is preferred to either sunn-hemp or jute. From the pith of the twigs curious mats are made in Assam.

STERCULIA VILLOSA, Roxb.; STERCULIACEÆ.—*Udal, udar*, Hind.

Ultimate Fibre.—Length, 2-4 mm.

A moderate-sized tree of the sub-Himálayan tract from the Indus eastward; common in forests throughout India and Burma.

The tree is highly valued on account of the fibre obtained from the inner bark, which is coarse but strong, and is made into ropes and bags. The tree is so highly valued for its fibre that in the more accessible forests it may be said to occur chiefly as a bush, from the habit of constantly lopping its branches for the fibre they contain.

In Burma it is extensively used in the manufacture of the strong ropes required to fasten elephants. Perhaps no fibre in India deserves to be more carefully examined for the purposes

of the rope trade. A strong rope could be produced, but it may be doubtful whether the colour and lustre essential to a good selling rope, could be obtained without expensive preparation.

In so far as this report is a record of the results of joint investigations undertaken in connection with the Colonial and Indian Exhibition, it must be considered to end here. Dr. Watt having, however, contributed an account of Indian cottons and flosses, as well as of some unclassified vegetable fibrous products, we could not do otherwise than include the additional matter, which will have especial interest for some readers.—C., B. & K.

PART III.

COTTON.

COTTON is the most important of all fibres, and is extensively cultivated in India. There are three well-known species, and the cultivated forms are varieties or hybrids of these. In the present state of our knowledge of the cottons of India, it is impossible to say how much of each species and its forms are actually cultivated, but it may be stated that the better cottons of the western side of India are chiefly forms of the American (*Gossypium barbadense*) plant, while that from the eastern side of India is mainly the Asiatic species (*Gossypium herbaceum*). The following extract from the 'Official Catalogue of the Colonial and Indian Exhibition' gives an abstract of all that is known regarding Indian cotton and the Indian trade in this most important fibre:—

Cotton is the most valuable article of Indian export trade. In India there are 14,000,000 acres annually under cotton, not including Bengal and Assam; of these provinces the cotton returns are not published. The following are the quantities and values of the cotton exports for the past five years.—

	Cwt.	Rupees.
1880-81	4,541,539	13,24,17,341
1881-82	5,627,453	14,93,59,595
1882-83	6,168,278	16,04,90,174
1883-84	5,979,494	14,38,37,278
1884-85	5,066,057	13,28,63,673

The exports for 1884–85 were about 15 per cent. smaller in quantity and 7½ per cent. less in value than those for 1883-84. This depression, Mr. O'Conor explains, was due to a short and inferior crop of Bombay cottons.

It is remarkable how unimportant India is as a supply of cotton for the English market. Out of the whole exports for

1884–85, the Continent imported direct 2,513,807 cwt., and England 2,134,762, but nearly half the amount consigned to England was re-exported again to the Continent of Europe. To the English manufacturer, therefore, Indian cotton is, comparatively speaking, of secondary importance; Italy offers the largest market.

The following analysis of the exports for the year 1884–85 shows the chief markets to which Indian cottons are consigned:—

Presidency from which Exported.	Weight in Cwt.	Value in Rupees.	Country to which Exported.	Weight in Cwt.	Value in Rupees.
Bengal .	288,976	68,82,064	United Kingdom.	2,134,762	5,58,86,298
Bombay .	4,064,609	10,88,52,143	Italy . .	740,647	1,90,78,004
Sindh . .	71,660	17,45,986	France .	577,169	1,52,80,431
Madras .	557,877	1,34,72,806	Austria .	575,645	1,55,54,204
British Burma	82,935	19,10,674	Belgium .	533,993	1,41,88,184
			China . .	236,600	58,51,838
			Germany .	85,353	23,19,504
			Other Countries.	181,888	47,05,210
TOTAL .	5,066,057	13,28,63,673	TOTAL .	5,066,057	13,28,63,673

Much confusion still exists with regard to the forms of cotton met with in cultivation in India, and it may therefore be of service to repeat here the characters of the leading species. There are in India three species of *Gossypium* which yield cotton, but of these there are many varieties and hybrids, giving origin to the numerous forms known to the cultivator and manufacturer by local and technical names. The three species may be briefly defined:—

*GOSSYPIUM ARBOREUM, Linn.; MALVACEÆ.

This is known as *narma*, *manua*, or *radya* cotton in India generally, and in Mysore as *deo kapás*. It does not appear to be cultivated to a great extent. It sometimes attains the height of a small tree; more frequently it is a densely branched bush, with purple flowers, often with a yellow centre. The *leaves* are thicker and more glossy than those of the next species; they are three-fourths segmented, or even cut to the base, into five to seven lobes (mostly five, never three); the segments are contracted below, narrow ovate, linear, acuminate or ovate lanceolate, not one-fourth as broad as long;

the central lobe often has, on either side, a small supplementary segment or tooth in the deep rounded lateral sinus. *Bracteoles* of the flowers ovate, cordate acute, toothed or entire. *Seeds* free from each other, covered with a white cotton overlying a dense green down; *cotton* not readily separable from the seed.

This is now viewed as a native of tropical Africa.

*G. BARBADENSE, Linn.

There are many very distinct cultivated forms referred to this species. Whether the accepted type is the original condition of the plant, however, or is itself only one of the numerous cultivated forms, can only be determined when the whole subject of the wild cottons of America (the wild cottons which exist as such at the present day) has been carefully worked out. At the time of the discovery of America the forms of cotton now referred to this species were being cultivated from the West Indies to Peru, and from Mexico to Brazil. Accepting this as evidence that they were the cultivated forms of an indigenous species, the more so since, as far as can be learned, they were not known to the Old World before the discovery of America—we may adopt the general view and regard them collectively as "the American cottons." According to some botanists these are referred to a number of distinct species, or by others are reduced to varieties under a somewhat hypothetical species. Parlatore relegated the numerous conditions to three species, which answer to *Gossypium hirsutum*, *G. barbadense*, and *G. religiosum*, Linn. The authors of the 'Flora of British India' group a number of forms, including the above, into one species, namely, *G. barbadense*.

G. barbadense may be distinguished from the other species as follows:—*Leaves* sub-glabrous, broader and more cordate than those of the preceding species, having rounded ears at the base: blade about half cut into three to five lobes, each broad ovate, acuminate, more than half as broad as long (often very acuminate and then almost sub-lanceolate). Floral *bracteoles*, larger and broader than in the preceding species, obtuse, deeply laciniate. *Flowers* yellow with a crimson spot. *Seeds* black and naked, i.e. destitute of adnate pubescence (except var. *religiosum*), free from each other or cohering in a kidney-shaped mass. *Cotton* readily separable from the seeds, white, tawny, or almost brown.

This may be reduced to three varieties:—

Var. 1st.—BARBADENSE proper.

The Bourbon cottons and the Barbadoes, New Orleans, Sea Island, Uplands, Egyptian, Georgian, Florida, and Alabama cottons. The much-prized cotton cultivated in Western India, and known as Dharwar, appears to be a form of New Orleans.

Var. 2nd.—RELIGIOSUM, Roxb.—Nankeen cotton.

The distinguishing feature of this cotton seems to be that the seeds are clothed with tawny pubescence and inclosed in cotton of the same colour. Apparently this was introduced into India at a much earlier date than the forms referred to the first variety, and as it exists at the present day it might be more correctly viewed as a hybrid, hence the fact of the seeds being pubescent.

Var. 3rd.—ACUMINATUM, Roxb.—Peruvian or kidney cotton.

The cottons which fall into this variety are distinguished chiefly by the peculiarity of the black naked seeds cohering together in a kidney-shaped mass. It is probable that these are even still earlier introductions than the forms of *religiosum*, and Roxburgh seemed to incline to the opinion that they were indigenous. They are sometimes spoken of under the name of *Gossypium peruvianum*. The following are the principal commercial forms:—Brazilian, Pernambuco, Maranham, and Peruvian and the *Ukan paruthi* and *Jadi paruthi* of Madras, and the long kidney cottons of the Gáro and Khásia hills.

It seems probable that instead of *Gossypium hirsutum*, Willd., being constituted into a fourth variety, it should be viewed as a distinct hybrid between *G. herbaceum* and *G. barbadense*. It is chiefly characterised by having greenish tomentose seeds surrounded by a fine long silky cotton, and by having purple flowers with the leaves of the American forms. A good deal of the Berar and Surat cottons, and also the *nudum yerra prathi*, and *semparuthi* of South India are of this nature.

GOSSYPIUM HERBACEUM, Linn.

There seems no doubt about this species having been originally a native of Asia, and of India in particular. A wild species, closely allied, is said to occur in Sind at the present day, which may prove the parent of the cultivated forms. Its cultivation has, however, spread all over the world—it is common in Europe, Asia, and the United States. To admit of comparison with the species described above, the diagnostic characters of this species may be here given:—*Leaves* very hairy; often quite hirsute; about half cut into three to five lobes, mostly three; lobes ovate, oblong, acute, or acuminate; about half as broad as long. Floral *bracteoles* ovate, cordate, acute, toothed or entire. *Flowers* yellow with a purple centre, or rarely wholly yellow or white or purple. *Seeds* ovoid, free from each other, covered with greyish or greenish down, cotton white or yellow. The most characteristic features of this plant are its very hairy leaves, half segmented, the majority having only three lobes or five, very rarely seven. The bracteoles are those of *Gossypium arboreum*, and are quite unlike the laciniated bracteoles of *G. barbadense*. The purple flowers and green tomentum of some of the forms has most probably been derived by hybridism with *G. arboreum;* some such hybrid being again crossed with *G. barbadense* to produce a few of the cultivated forms, such as *G. hirsutum*, which possesses the characters of all three species.

There seems to be little doubt that *G. herbaceum* has been hybridised freely with both of the preceding species, and that many of the cultivated forms of cotton met with in India are of this nature. Efforts appear to have been made to improve the indigenous plant by crossing it with the superior though less hardy and introduced species. The hybrids and cultivated forms of this species may conveniently be referred to two sections:—

Var. 1st.—HERBACEUM proper.

This includes the Bengal or Dacca cottons, and many of the Berar and Surat—such as the *Kumari hatti* of South Kanara and *Punasa pratti* of Ganjam, as also some of the China cottons.

Var. 2nd.—OBTUSIFOLIUM.

This is the small blunted-leaved form met with in Ceylon and on many of the hill tracts of India.

Cotton is the principal article of export trade from Bombay. There are eight leading kinds: *Hinganghát* and *Amráoti* from the Central Provinces, Berár, Khándesh, the Nizam's country, and the North Deccan; *Broach* and *Dholera* from Gujarat, Kathiawar, and Cutch; *Saw-ginned Dharwar* and *Coompta* from the Southern Maratha Districts and Sholapur; *Westerns* from Madras; and *Iráni* from Persia.

Silk Cottons.

Interest has recently been taken in the subject of "silk cotton" and *kapok*. The following are the plants which yield this floss, enumerated in the order of their importance:—

ERIODENDRON ANFRACTUOSUM, DC.; MALVACEÆ.—The *Kapok*, or white silk cotton; the *Elavam paruthi* of Madras.

This tree is particularly plentiful in the Konkan and Western India generally, but it grows in most parts of India, and its cultivation could be extended. As a road-side tree, while affording shade, it might thus be made to yield a distinct revenue to the country.

Both in English and Australian trade the word *kapok* is by some dealers used as synonymous with "silk cotton," but it seems desirable that this should be avoided. Up till the past few years silk cotton has been accepted as the floss of *Bombax*, or the *semal* of India. The two fibres have not only different values, but are likely to enter widely different markets. The *kapok* of Java seems superior to the *kapok* of India, but this may be corrected by more careful selection of seed in cultivation. At the present moment it is, however, doubtful if a single consignment of *kapok* has been sent from India to Europe.

BOMBAX MALABARICUM, DC.; MALVACEÆ.—The *Semal*, or red silk cotton.

This is the commonest of the silk cotton trees, occurring throughout the peninsula, but more particularly on the eastern side, ascending the hills to 4000 feet in altitude.

Hitherto this fibre has been found too short and too light for textile purposes, and, moreover, the dirty state of all consignments, burdened with the seeds, has precluded the *semal* from competition with the Java *kapok* in upholstery.

COCHLOSPERMUM GOSSYPIUM, DC; BIXINEÆ.—The *Kambi* or *Galgal*.

A common tree of the lower hills of India from Garhwal, Bandelkhand, Behar, Orissa, and westward to the Deccan. It has large yellow flowers, and is not uncommon in cultivation throughout the country, especially in South India. The fibre is soft and silky but very short. It could be supplied at a much lower rate than the *kapok* and has a resistance about it which prevents it from matting like the *semal* when used in upholstery. With the exception of the sample shown at the last Exhibition in London, it is believed, this fibre has not as yet been placed in the hands of the European manufacturer.

CALOTROPIS GIGANTEA, R. Br.; ASCLEPIADEÆ.—The *Madar*.

This and other members of the *Asclepiadaceæ* and *Apocynaceæ* yield silky hairs—the coma of the seeds. These are generally classed as silk cottons, but with the exception of *madar*, none of these have as yet been experimented with. The natives of India regard the *madar* silk cotton as much cooler than *semal*, and affirm that it has a soothing effect when used in pillows.

During the Colonial and Indian Exhibition a cotton spinner explained that he had now been able to utilise this fibre by mechanically drawing it in with cotton in the preparation of yarn. The difficulty he now experienced was in procuring a uniform supply. It was agreed that the best plan to secure this necessary condition towards the establishment of a new industry was to induce the people of India to attempt its cultivation. It was presumed moreover that by selection of seed and cultivation the quality of the fibre might be greatly improved. With this object in view, a gentleman in India was induced to attempt the cultivation, and already the spinner reports his entire satisfaction in the results of the experiment. It may thus be confidently hoped that in a few years *madar* fibre (of which so much has been written during the past fifty years) may at last be viewed as an established new industry, that will greatly benefit the poor cultivators of a large tract of the less productive portions of India. As a wild plant it luxuriates in the waste, almost sterile and dry tracts of India.

FIBRES EMPLOYED IN BASKET-WORK AND IN THE MANUFACTURE OF MATS, &C.

This list might be greatly extended, but it has been deemed advisable to restrict it to the more important only. The various species of bamboo are everywhere in India made into baskets, mats, &c., rice straw, and the stems of many other grasses such as *saccharum munjab*, also are extensively employed for the finer qualities of baskets and table mats.

ANDROPOGON MURICATUS, Retz.; GRAMINEÆ.—*Khas*, Hind.; *Khas-khas*, Beng.

A grass, abundant on sandy banks in Bengal, Upper India, the Coromandel Coast, and Mysore, where it is commonly planted to divide fields.

The roots are in India made into the aromatic-scented mats which are hung over doors and kept wet to cool the atmosphere in the hot season, and are also in great demand for making fans, &c.

ARUNDO KARKA, Retz.; GRAMINEÆ.—Vern. Names. *Karka, Nal*, Bengali; *Nudanur*, Hindustani; *Bag, Narí*, Panjabi.

This plant grows chiefly on the lower hills and outer slopes of the Himálaya, but an allied species is found in damp places in Bengal.

The stems are brought down to the plains and sold as *nal*. These are split open and formed into the square mats known as *darmá* mats, of which the houses in Bengal and a large part of the North-west Provinces of India are almost exclusively constructed.

These are sold very cheap, and at one of the conferences held at the late Exhibition, it was suggested an effort might be made to try and introduce these cheap mattings into England. They were thought likely to be in demand to line the inner sides of iron roofed houses or as matting for the floors of the houses of the poor.

BAMBOO.

The principal bamboos employed for baskets and matting are *Bambusa arundinacea* (in Central and South India), *B. balcooa* and *B. tulda* (in Bengal), and *B. arundinacea* and *B. brandisii* (in Burma), with *Dendrocalamus strictus* wherever that species could be obtained. The houses of the people of three-fourths of India are made almost entirely of bamboo and darmá mats, but in Burma they are mostly of bamboo split open into flat slabs, neatly platted into mats.

In some parts of Bengal, such as in Midnapur, *Dendrocalamus strictus* is split into extremely fine pieces, and woven into elegant, though very expensive mats. Portions are coloured in deep red, working out graceful patterns and borders.

CYPERUS TEGETUM, Roxb.; CYPERACEÆ.—The grass matting of Bengal.

The subject of mat-grasses is exceedingly obscure, but it seems probable that any large *Scirpus* may be used for this purpose. The better qualities of Calcutta mats are made from *C. tegetum*, but as this plant is not found near Calcutta (although common in Orissa and Chutia Nagpur), the prepared mat fibre must be imported. The commoner mats are made of *C. articulatus*, *C. procerus*, and *C. exaltatus*. The grass-mats of the Sandwich Islands are made of *C. lævigatus*, a species common in Madras, but apparently never made into mats in India. Ceylon mats are made of a species allied to, if not identical with *C. malaccensis*. Grass-mats are made in Bombay from *Scirpus subulatus*.

CALAMUS ROTANG, Linn.; PALMÆ.—The rattan cane.

This and several allied species of cane are met with in many of the moister parts of India, especially in Bengal, Assam, South India, and Burma.

This yields the true rattan cane of commerce, but others are of course used as substitutes. It is, as in Europe, split into strips and extensively woven into baskets, chairs, and carriages, &c. It is often twisted into ropes, and the entire cane is frequently stretched across rivers, forming the main supports to suspension bridges. A cane 400 to 600 feet long may easily be procured for this purpose, and sufficiently strong that two such canes are sufficient to bear the weight of the bridge suspended from them. The natives of the Naga hills are able to stain the surface layer of the rattan, which they plat into the leggings and bracelets which they wear.

IVORY MATS.

In Assam, Manipur, and one or two other places, ivory is cut into strips so fine that it is woven into elegant mats. These cost as much as 50*l.* to 150*l.*, and have often gold platted into the borders.

MARANTA DICHOTOMA, Wall.; SCITAMINEÆ.—*Pati*, Beng.

A reed-like plant found in Eastern Bengal, Assam, the Coromandel Coast, and Burma. The stems are slit into strips, and platted into the so-called *Shital-pati* mats. These are smooth mats, which, owing to their coolness, are largely used in the hot weather for sleeping on. Some of the finest cost about 5*l.* each, but the ordinary kinds average from R.2 to 3.

PARROTIA JACQUEMONTIANA, Decaisne; HAMAMELIDEÆ.

A large deciduous shrub of the North-west Himálaya.

The chief use of the wood of this plant is in basket work, and the bark is platted into the ropes which are made into bridges. The twigs are very tough and flexible, and the bridges made of these may often be seen 300 feet long.

PHŒNIX SYLVESTRIS, Roxb.; PALMÆ.—The wild date palm; *Khajur*, Hind.

A palm with ashy-grey foliage, cultivated throughout India. The fibrous leaflets and the fibre from the petioles are made into mats, ropes, and baskets. The fibre produced by cutting the leaves into strips may come to be used as a paper material.

SALIX (very many species).

The willow, as in Europe, is largely employed in the manufacture of baskets, especially the small strong baskets brought down to the plains and used for agricultural purposes.

SESBANIA ÆGYPTIACA, Pers.; LEGUMINOSÆ.

The soft pithy stems of this plant are, in Assam, platted into curious mats, portions of which are dyed black before being matted, so as to work out a bold pattern.

MISCELLANEOUS FIBRES.

Fibrous substances not included in either of the foregoing groups, such as the tomentum from leaves and the hairs from scales, &c., &c., also fibro-vascular bundles used as cords in place of twisted or spun thread or string.

ARENGA SACCHARIFERA, Labill.; PALMÆ.—The sago palm or *Gumúté* palm.

A Malayan palm, cultivated in many parts of India, but met with in a wild state in Burma and Manipur, and probably wild also in Orissa.

Within the leaf sheath is found a layer of fine reticulated tissue, said to be in great demand in China, and employed like oakum in caulking the seams of boats. It is also largely used as tinder, and the Manipuris employ it in the construction of mechanical filters. The fibre has a high reputation for lasting under water.

BORASSUS FLABELLIFORMIS, Linn.; PALMÆ.—The Palmyra palm; *Tal* or *tar*, Hind.

A tall palm, common all over India, and extending much further into the interior of the country than the cocoa-nut.

The tomentum from the leaf-scales and flower-buds is used as a tinder. A single fibro-vascular thread is employed in Bengal for fishing lines or traps.

CARYOTA URENS, Linn.; PALMÆ.—*Salopa*, Uriya; *Simong*, Lepcha; *Minbaw*, Burmese; *Kittul*, Cinghalese.

A beautiful palm, met with in the forests of the western and eastern moist zones.

The cord-like fibre from the sheathing petioles is made into ropes, fishing-nets, lines, &c., and in Europe a large trade has sprung up in the employment of this fibre in the manufacture of brushes. A sample shown at the Colonial and Indian Exhibition was much admired, and pronounced superior to the *kittul* obtained from Ceylon. It is remarkable, however, that the entire market should be met by Ceylon, when the forests of India might easily afford an unlimited amount of *kittul*. The fibro-vascular cords from the interior of the stem of *caryota* were by a corset manufacturer pronounced a hopeful substitute for whalebone.

GERBERA LANUGINOSA, Benth.; COMPOSITÆ.

A common herbaceous plant found on the mountains of Manipur and throughout the entire range of the Himálaya, at an altitude of from 5000 to 8000 feet.

The tomentum from the under surface of the leaves is universally used as tinder. This is known as *kapasiya*. A thread is sometimes spun of this curious fibre and woven into bags, in which the natives of Kumaun carry their hookahs. These bags are known as *kupasis*.

GNAPHALIUM spp.; COMPOSITÆ.

The tomentum from the under surface of the leaves of various species of *gnaphalium* is used as tinder by the hill tribes of India. This is removed by rubbing between the hands withered leaves. The cellular tissue crumbles away, leaving the woolly tomentum

in the hands. This is easily ignited by friction. A small hole dug in the ground is filled with the tomentum, and a pointed stick rapidly rotated in it by means of a string drawn backwards and forwards.

Conclusion.

In the classification of the vegetable fibres according to the results of our investigations, we find certain points deserving of special mention. A general resemblance of the bast fibres of the plants constituting a natural order is perhaps to be expected. This resemblance in structural and chemical characteristics is, for instance, very marked in the Urticaceæ, the Malvaceæ, and Asclepiadeæ. It is also noteworthy that the fibres which have up to the present been recognised as of probable value to commerce, in addition to the limited number which constitute in such large quantities the staple of our western textile industries, are yielded by a very limited number of the natural orders.

Thus in the collection in question we find some thirty Dicotyledonous bast fibres obtained from the following orders:—Lineæ, 1; Urticeæ, 8; Asclepiadeæ, 2; Thymelæaceæ, 1; Meliaceæ, 1; Leguminosæ, 4; Malvaceæ, 8; Sterculiaceæ, 4; Tiliaceæ, 2; of which the last three are closely allied, constituting the Cohort Malvales.

A correlation interesting to note, is that of lignification with shortness of the ultimate fibre. We know no instance of a bast fibre having this characteristic of chemical composition, of which the length exceeds 5 mm. In regard to the theory of lignification, commonly accepted, we have found that in so far as it accounts for the particular chemical composition of lignified fibre, as an overlaying of a pure cellulose with "encrusting substances" of different composition, it is not in accordance with the facts. The evidence of the development of the fibre in the jute plant would lead us to conclude that the lignocelluloses are primary plant-constituents in the same sense that the celluloses are; and the same is probably also true of the pectocelluloses. This is a part of the subject which requires extended investigation. Thus far we have little but indirect deductions supported by conjecture to go upon in regard to the chemistry of the origin and development of these plant-substances.

The evidence of these investigations confirms us in regarding the fibre substances as compound celluloses, and in this aspect they divide themselves into the two main groups, pectocelluloses, and lignocelluloses. We have not been able to follow Frémy in his classifications of these primary plant-constituents; the terms paracellulose, vasculose, cutose, &c., appear to us to rest upon somewhat insecure foundations; and the distinctions which they are stated to represent appear too special for a subject for which the broader lines of classification are not yet agreed upon amongst chemists.

Coming now to more special points,—

The most characteristic of the celluloses isolated from the fibres are those of Calotropis and Marsdenia. For softness and silky lustre they surpass all others that we have examined, and we should be glad to see more attention paid to these fibres, from the technical point of view.

In the jute class, Sida rhombifolia is the most conspicuously deserving of notice, and of probable commercial value.

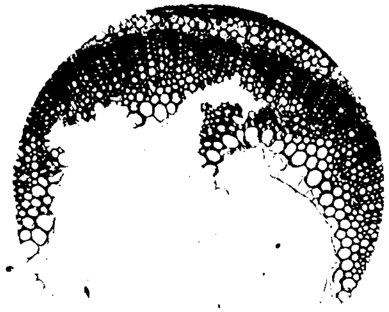
Of the Monocotyledonous fibres the only one calculated to win a place in the higher departments of the textile industries is, we think, the pine-apple fibre.

In the class of fibre aggregates, Division D. of our Classification, certain raw materials have been included as a result of the very imperfect preparation to which they have been subjected. In such an impure condition they are of course less interesting subjects for laboratory investigations, as indeed also they are less promising of practical applications outside the locality of their production. It is of interest to note that in nearly all cases the length of the ultimate fibre is small, and where this is so, we should, except on other grounds, decide that the fibre is comparatively not deserving of attention. We fully admit that there are other grounds, as, for instance, in the case of Bauhinia Vahlii, upon which technical value may be determined, as against inferiority in point of length of ultimate fibre. Still, experience has confirmed us in regarding the latter as the most trustworthy criterion of value.

On scientific grounds the Bauhinia fibre is interesting for the peculiar colouring matter which is associated with the bast; and the Sterculia bast may be cited as the only instance observed of a fibre yielding mucic acid by oxidation with nitric acid.

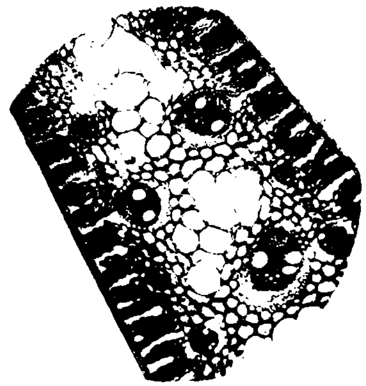
Many other points of special interest must remain unnoticed here. Should a further opportunity present itself of continuing these investigations, and under more favourable conditions, we may be able to embody our observations in a more substantially scientific contribution to the subject.

LONDON: PRINTED BY WILLIAM CLOWES AND SONS, LIMITED, STAMFORD STREET AND CHARING CROSS.

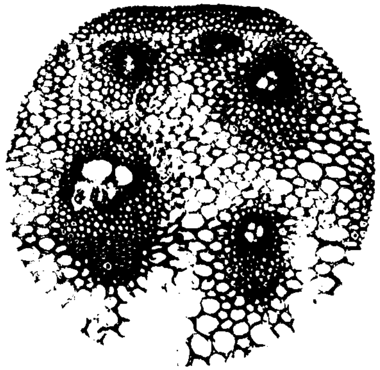


× 50. Fig. 1.

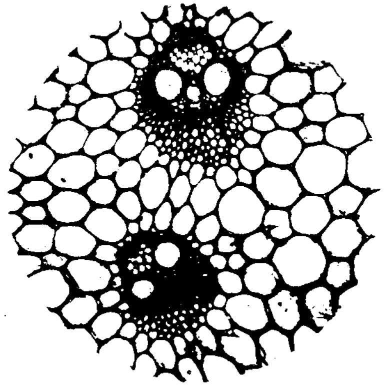
× 50. Fig. 2.



× 50. Fig. 3.

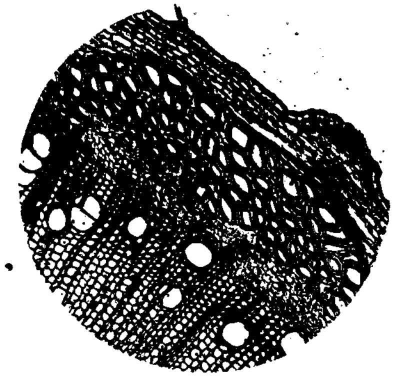


× 50. Fig. 4.



× 50. Fig. 5.

× 25. Fig. 6.

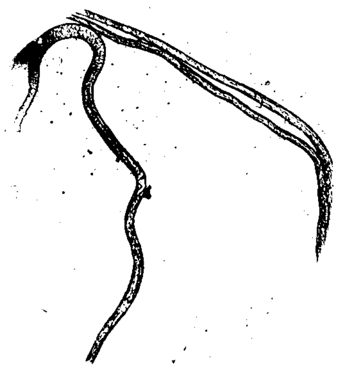


× 50. FIG. 7.

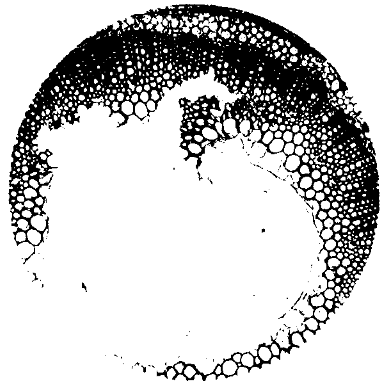
× 200. FIG. 8.

× 50. FIG. 9.

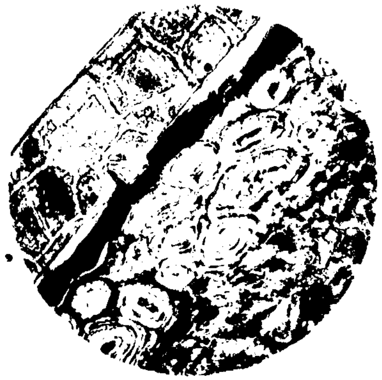
× 200. FIG. 10.



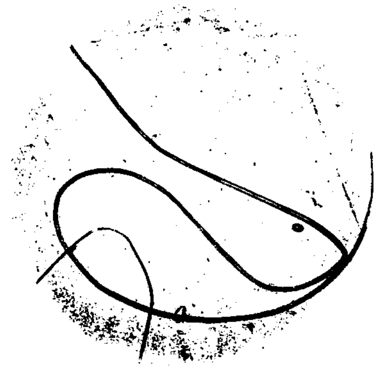
× 20. FIG. 11.



× 50. FIG. 12.

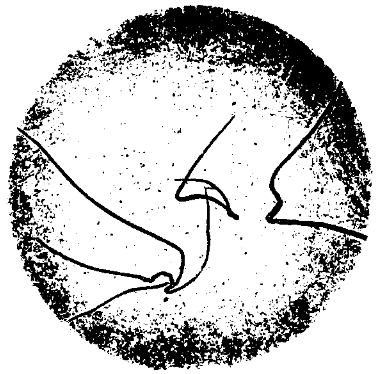


× 200. Fig. 13.

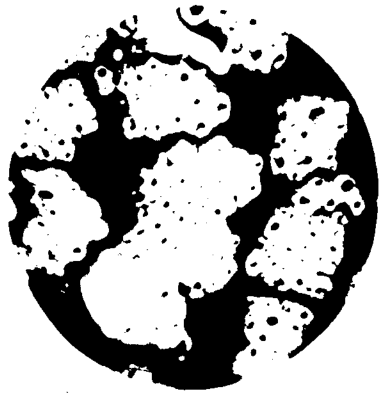


× 15. Fig. 14.

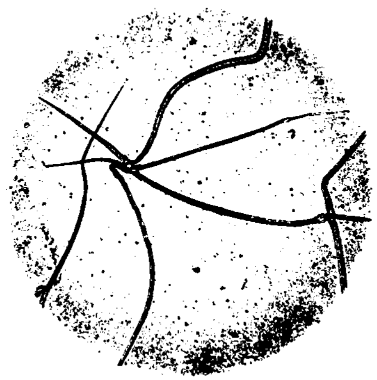
× 200. Fig. 15.



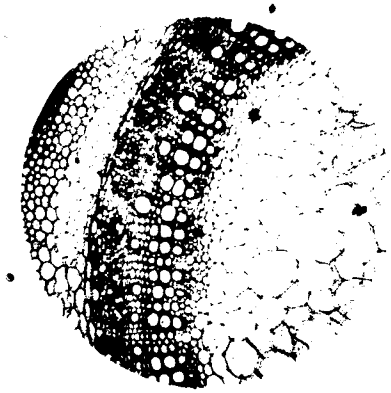
× 20. Fig. 16.



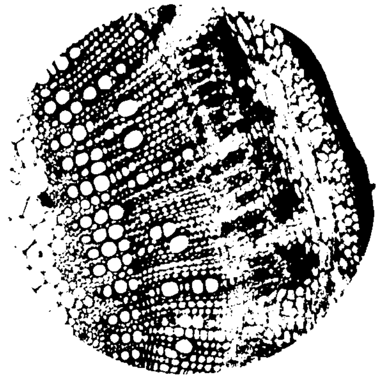
× 200. Fig. 17.



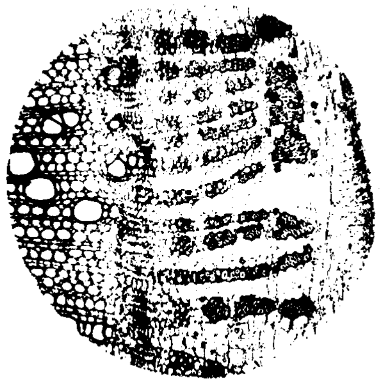
× 20. Fig. 18.



× 50. Fig. 19.



× 50. Fig. 20.

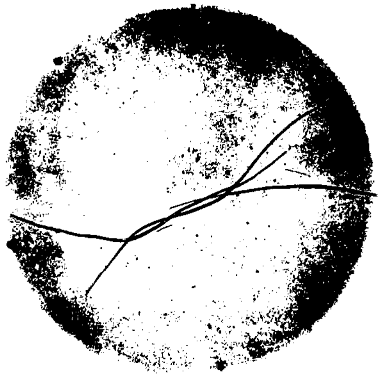


× 50. Fig. 21.

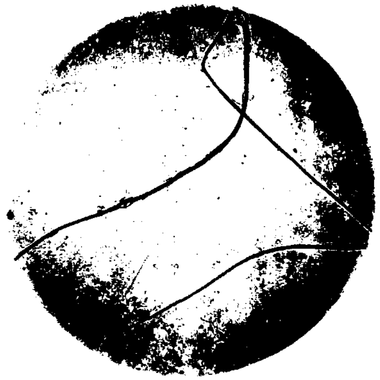
× 400. Fig. 22.

× 20. Fig. 23.

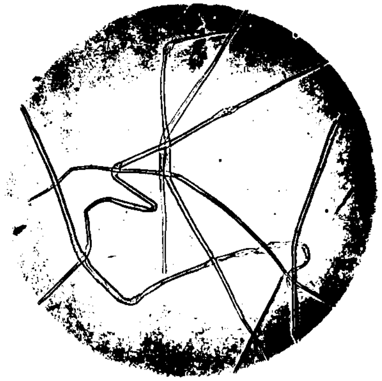
× 400. Fig. 24.



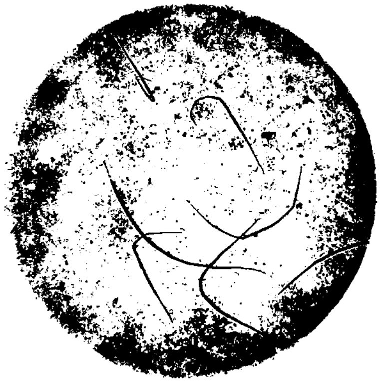
× 20. Fig. 25.



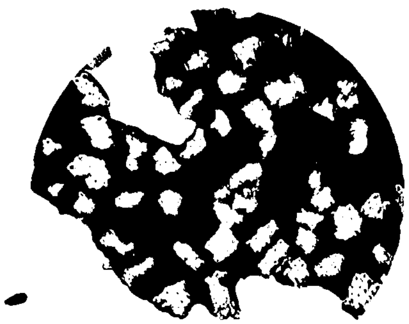
× 20. Fig. 26.



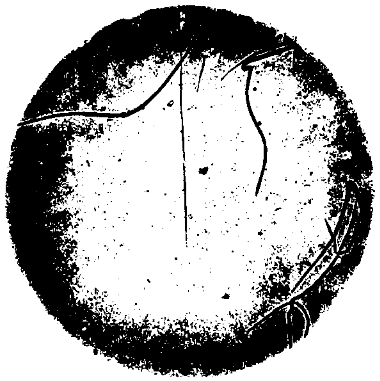
× 50. Fig. 27.



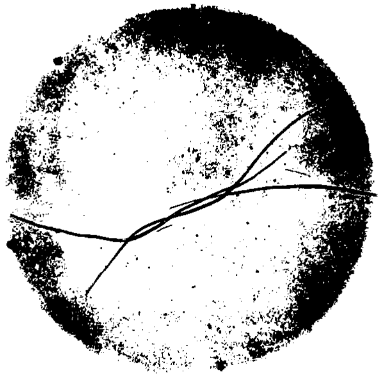
× 20. Fig. 28.



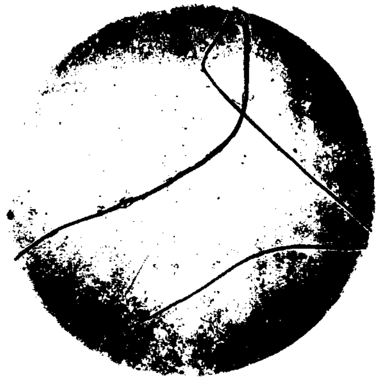
× 100. Fig. 29.



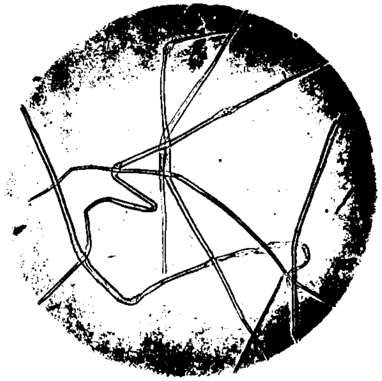
× 20. Fig. 30.



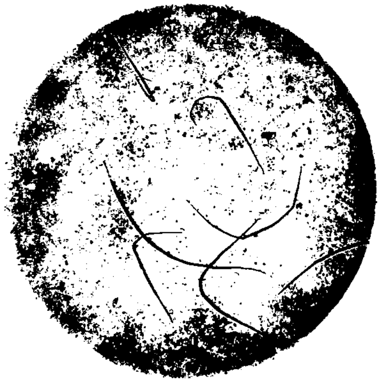
× 20. Fig. 25.



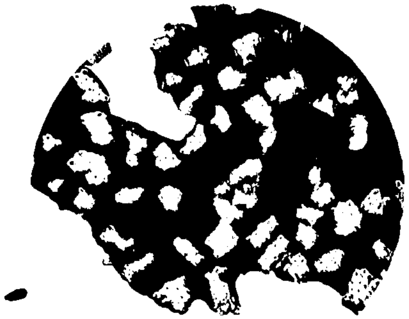
× 20. Fig. 26.



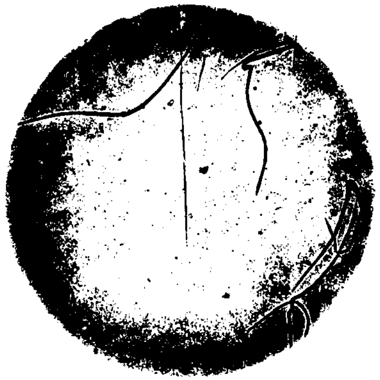
× 50. Fig. 27.



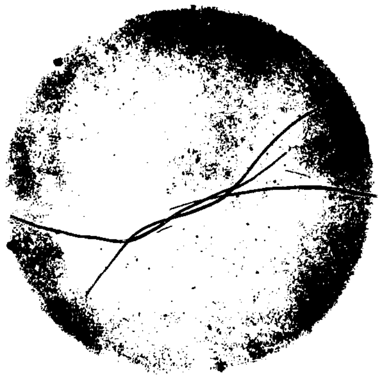
× 20. Fig. 28.



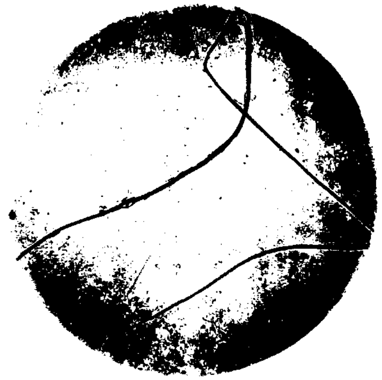
× 100. Fig. 29.



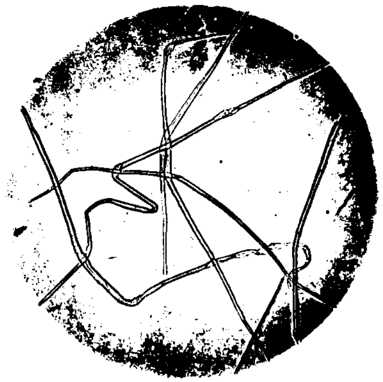
× 20. Fig. 30.



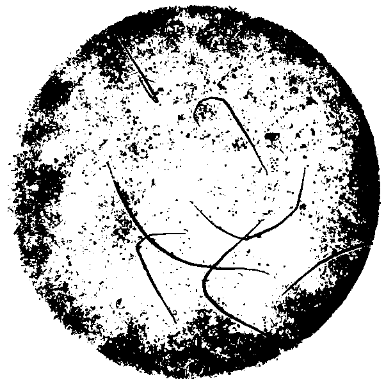
× 20. FIG. 25.



× 20. FIG. 26.

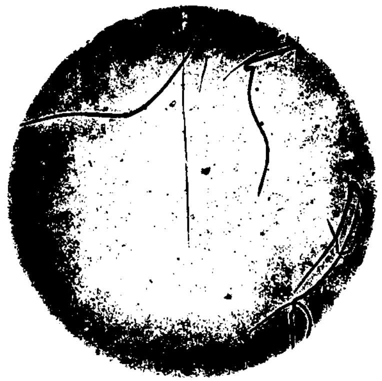


× 50. FIG. 27.



× 20. FIG. 28.

× 100. FIG. 29.



× 20. FIG. 30.

BOOKS RELATING

TO

APPLIED SCIENCE,

PUBLISHED BY

E. & F. N. SPON,

LONDON: 125, STRAND.

NEW YORK: 35, MURRAY STREET.

A Pocket-Book for Chemists, Chemical Manufacturers, Metallurgists, Dyers, Distillers, Brewers, Sugar Refiners, Photographers, Students, etc., etc. By THOMAS BAYLEY, Assoc. R.C. Sc. Ireland, Analytical and Consulting Chemist and Assayer. Fourth edition, with additions, 437 pp., royal 32mo, roan, gilt edges, 5*s*.

SYNOPSIS OF CONTENTS:

Atomic Weights and Factors—Useful Data—Chemical Calculations—Rules for Indirect Analysis—Weights and Measures—Thermometers and Barometers—Chemical Physics—Boiling Points, etc.—Solubility of Substances—Methods of Obtaining Specific Gravity—Conversion of Hydrometers—Strength of Solutions by Specific Gravity—Analysis—Gas Analysis—Water Analysis—Qualitative Analysis and Reactions—Volumetric Analysis—Manipulation—Mineralogy—Assaying—Alcohol—Beer—Sugar—Miscellaneous Technological matter relating to Potash, Soda, Sulphuric Acid, Chlorine, Tar Products, Petroleum, Milk, Tallow, Photography, Prices, Wages, Appendix, etc., etc.

The Mechanician: A Treatise on the Construction and Manipulation of Tools, for the use and instruction of Young Engineers and Scientific Amateurs, comprising the Arts of Blacksmithing and Forging; the Construction and Manufacture of Hand Tools, and the various Methods of Using and Grinding them; the Construction of Machine Tools, and how to work them; Machine Fitting and Erection; description of Hand and Machine Processes; Turning and Screw Cutting; principles of Constructing and details of Making and Erecting Steam Engines, and the various details of setting out work, etc., etc. By CAMERON KNIGHT, Engineer. *Containing 1147 illustrations,* and 397 pages of letter-press. Third edition, 4to, cloth, 18*s*.

On Designing Belt Gearing. By E. J. COWLING WELCH, Mem. Inst. Mech. Engineers, Author of 'Designing Valve Gearing.' Fcap. 8vo, sewed, 6*d.*

A Handbook of Formulæ, Tables, and Memoranda, for Architectural Surveyors and others engaged in Building. By J. T. HURST, C.E. Thirteenth edition, royal 32mo, roan, 5*s.*

"It is no disparagement to the many excellent publications we refer to, to say that in our opinion this little pocket-book of Hurst's is the very best of them all, without any exception. It would be useless to attempt a recapitulation of the contents, for it appears to contain almost *everything* that anyone connected with building could require, and, best of all, made up in a compact form for carrying in the pocket, measuring only 5 in. by 3 in., and about ¼ in. thick, in a limp cover. We congratulate the author on the success of his laborious and practically compiled little book, which has received unqualified and deserved praise from every professional person to whom we have shown it."—*The Dublin Builder.*

Tabulated Weights of Angle, Tee, Bulb, Round, Square, and Flat Iron and Steel, and other information for the use of Naval Architects and Shipbuilders. By C. H. JORDAN, M.I.N.A. Fourth edition, 32mo, cloth, 2*s.* 6*d.*

Quantity Surveying. By J. LEANING. With 42 illustrations. Second edition, revised, crown 8vo, cloth, 9*s.*

CONTENTS :

A complete Explanation of the London Practice.
General Instructions.
Order of Taking Off.
Modes of Measurement of the various Trades.
Use and Waste.
Ventilation and Warming.
Credits, with various Examples of Treatment.
Abbreviations.
Squaring the Dimensions.
Abstracting, with Examples in illustration of each Trade.
Billing.
Examples of Preambles to each Trade.
Form for a Bill of Quantities.
Do. Bill of Credits.
Do. Bill for Alternative Estimate.
Restorations and Repairs, and Form of Bill.
Variations before Acceptance of Tender.
Errors in a Builder's Estimate.
Schedule of Prices.
Form of Schedule of Prices.
Analysis of Schedule of Prices.
Adjustment of Accounts.
Form of a Bill of Variations.
Remarks on Specifications.
Prices and Valuation of Work, with Examples and Remarks upon each Trade.
The Law as it affects Quantity Surveyors, with Law Reports.
Taking Off after the Old Method.
Northern Practice.
The General Statement of the Methods recommended by the Manchester Society of Architects for taking Quantities.
Examples of Collections.
Examples of "Taking Off" in each Trade.
Remarks on the Past and Present Methods of Estimating.

A Complete Set of Contract Documents for a Country Lodge, comprising Drawings, Specifications, Dimensions (for quantities), Abstracts, Bill of Quantities, Form of Tender and Contract, with Notes by J. LEANING, printed in facsimile of the original documents, on single sheets fcap., in paper case, 10*s.*

A Practical Treatise on Heat, as applied to the Useful Arts; for the Use of Engineers, Architects, &c. By THOMAS BOX. *With* 14 *plates.* Third edition, crown 8vo, cloth, 12*s.* 6*d.*

A Descriptive Treatise on Mathematical Drawing Instruments: their construction, uses, qualities, selection, preservation, and suggestions for improvements, with hints upon Drawing and Colouring. By W. F. STANLEY, M.R.I. Fifth edition, *with numerous illustrations,* crown 8vo, cloth, 5*s.*

Spons' Architects' and Builders' Pocket-Book of Prices and Memoranda. Edited by W. YOUNG, Architect. Royal 32mo, roan, 4*s.* 6*d.*; or cloth, red edges, 3*s.* 6*d.* *Published annually.* Thirteenth edition. *Now ready.*

Long-Span Railway Bridges, comprising Investigations of the Comparative Theoretical and Practical Advantages of the various adopted or proposed Type Systems of Construction, with numerous Formulæ and Tables giving the weight of Iron or Steel required in Bridges from 300 feet to the limiting Spans; to which are added similar Investigations and Tables relating to Short-span Railway Bridges. Second and revised edition. By B. BAKER, Assoc. Inst. C.E. *Plates,* crown 8vo, cloth, 5*s.*

Elementary Theory and Calculation of Iron Bridges and Roofs. By AUGUST RITTER, Ph.D., Professor at the Polytechnic School at Aix-la-Chapelle. Translated from the third German edition, by H. R. SANKEY, Capt. R.E. With 500 *illustrations,* 8vo, cloth, 15*s.*

The Builder's Clerk: a Guide to the Management of a Builder's Business. By THOMAS BALES. Fcap. 8vo, cloth, 1*s.* 6*d.*

The Elementary Principles of Carpentry. By THOMAS TREDGOLD. Revised from the original edition, and partly re-written, by JOHN THOMAS HURST. Contained in 517 pages of letter-press, and *illustrated with* 48 *plates and* 150 *wood engravings.* Fourth edition, reprinted from the third, crown 8vo, cloth, 12*s.* 6*d.*

Section I. On the Equality and Distribution of Forces—Section II. Resistance of Timber—Section III. Construction of Floors—Section IV. Construction of Roofs—Section V. Construction of Domes and Cupolas—Section VI. Construction of Partitions—Section VII. Scaffolds, Staging, and Gantries—Section VIII. Construction of Centres for Bridges—Section IX. Coffer-dams, Shoring, and Strutting—Section X. Wooden Bridges and Viaducts—Section XI. Joints, Straps, and other Fastenings—Section XII. Timber.

Our Factories, Workshops, and Warehouses: their Sanitary and Fire-Resisting Arrangements. By B. H. THWAITE, Assoc. Mem. Inst. C.E. *With* 183 *wood engravings,* crown 8vo, cloth, 9*s.*

Gold: Its Occurrence and Extraction, embracing the Geographical and Geological Distribution and the Mineralogical Characters of Gold-bearing rocks; the peculiar features and modes of working

Shallow Placers, Rivers, and Deep Leads; Hydraulicing; the Reduction and Separation of Auriferous Quartz; the treatment of complex Auriferous ores containing other metals; a Bibliography of the subject and a Glossary of Technical and Foreign Terms. By ALFRED G. LOCK, F.R.G.S. *With numerous illustrations and maps*, 1250 pp., super-royal 8vo, cloth, 2*l.* 12*s.* 6*d.*

A Practical Treatise on Coal Mining. By GEORGE G. ANDRÉ, F.G.S., Assoc. Inst. C.E., Member of the Society of Engineers. *With 82 lithographic plates.* 2 vols., royal 4to, cloth, 3*l.* 12*s.*

Iron Roofs: Examples of Design, Description. *Illustrated with 64 Working Drawings of Executed Roofs.* By ARTHUR T. WALMISLEY, Assoc. Mem. Inst. C.E. Second edition, revised, imp. 4to, half-morocco, 3*l.*

A History of Electric Telegraphy, to the Year 1837. Chiefly compiled from Original Sources, and hitherto Unpublished Documents, by J. J. FAHIE, Mem. Soc. of Tel. Engineers, and of the International Society of Electricians, Paris. Crown 8vo, cloth, 9*s.*

Spons' Information for Colonial Engineers. Edited by J. T. HURST. Demy 8vo, sewed.

No. 1, Ceylon. By ABRAHAM DEANE, C.E. 2*s.* 6*d.*

CONTENTS:

Introductory Remarks—Natural Productions—Architecture and Engineering—Topography, Trade, and Natural History—Principal Stations—Weights and Measures, etc., etc.

No. 2. Southern Africa, including the Cape Colony, Natal, and the Dutch Republics. By HENRY HALL, F.R.G.S., F.R.C.I. With Map. 3*s.* 6*d.*

CONTENTS:

General Description of South Africa—Physical Geography with reference to Engineering Operations—Notes on Labour and Material in Cape Colony—Geological Notes on Rock Formation in South Africa—Engineering Instruments for Use in South Africa—Principal Public Works in Cape Colony: Railways, Mountain Roads and Passes, Harbour Works, Bridges, Gas Works, Irrigation and Water Supply, Lighthouses, Drainage and Sanitary Engineering, Public Buildings, Mines—Table of Woods in South Africa—Animals used for Draught Purposes—Statistical Notes—Table of Distances—Rates of Carriage, etc.

No. 3. India. By F. C. DANVERS, Assoc. Inst. C.E. With Map. 4*s.* 6*d.*

CONTENTS:

Physical Geography of India—Building Materials—Roads—Railways—Bridges—Irrigation—River Works—Harbours—Lighthouse Buildings—Native Labour—The Principal Trees of India—Money—Weights and Measures—Glossary of Indian Terms, etc.

A Practical Treatise on Casting and Founding, including descriptions of the modern machinery employed in the art. By N. E. SPRETSON, Engineer. Third edition, with 82 *plates* drawn to scale, 412 pp., demy 8vo, cloth, 18*s.*

The Depreciation of Factories and their Valuation. By EWING MATHESON, M. Inst. C.E. 8vo, cloth, 6*s.*

A Handbook of Electrical Testing. By H. R. KEMPE, M.S.T.E. Fifth edition, revised and enlarged, crown 8vo, cloth, 16*s.*

Gas Works: their Arrangement, Construction, Plant, and Machinery. By F. COLYER, M. Inst. C.E. *With 31 folding plates,* 8vo, cloth, 24*s.*

The Clerk of Works: a Vade-Mecum for all engaged in the Superintendence of Building Operations. By G. G. HOSKINS F.R.I.B.A. Third edition, fcap. 8vo, cloth, 1*s.* 6*d.*

American Foundry Practice: Treating of Loam, Dry Sand, and Green Sand Moulding, and containing a Practical Treatise upon the Management of Cupolas, and the Melting of Iron. By T. D. WEST, Practical Iron Moulder and Foundry Foreman. Second edition, *with numerous illustrations*, crown 8vo, cloth, 10*s.* 6*d.*

The Maintenance of Macadamised Roads. By T. CODRINGTON, M.I.C.E, F.G.S., General Superintendent of County Roads for South Wales. 8vo, cloth, 6*s.*

Hydraulic Steam and Hand Power Lifting and Pressing Machinery. By FREDERICK COLYER, M. Inst. C.E., M. Inst. M.E. *With 73 plates,* 8vo, cloth, 18*s.*

Pumps and Pumping Machinery. By F. COLYER, M.I.C.E., M.I.M.E. *With 23 folding plates,* 8vo, cloth, 12*s.* 6*d.*

Pumps and Pumping Machinery. By F. COLYER. Second Part. *With 11 large plates,* 8vo, cloth, 12*s.* 6*d.*

The Municipal and Sanitary Engineer's Handbook. By H. PERCY BOULNOIS, Mem. Inst. C.E., Borough Engineer, Portsmouth. *With numerous illustrations,* demy 8vo, cloth, 12*s.* 6*d.*

CONTENTS:

The Appointment and Duties of the Town Surveyor—Traffic—Macadamised Roadways—Steam Rolling—Road Metal and Breaking—Pitched Pavements—Asphalte—Wood Pavements—Footpaths—Kerbs and Gutters—Street Naming and Numbering—Street Lighting—Sewerage—Ventilation of Sewers—Disposal of Sewage—House Drainage—Disinfection—Gas and Water Companies, &c., Breaking up Streets—Improvement of Private Streets—Borrowing Powers—Artizans' and Labourers' Dwellings—Public Conveniences—Scavenging, including Street Cleansing—Watering and the Removing of Snow—Planting Street Trees—Deposit of Plans—Dangerous Buildings—Hoardings—Obstructions—Improving Street Lines—Cellar Openings—Public Pleasure Grounds—Cemeteries—Mortuaries—Cattle and Ordinary Markets—Public Slaughter-houses, etc.—Giving numerous Forms of Notices, Specifications, and General Information upon these and other subjects of great importance to Municipal Engineers and others engaged in Sanitary Work.

Tables of the Principal Speeds occurring in Mechanical Engineering, expressed in metres in a second. By P. KEERAYEFF, Chief Mechanic of the Obouchoff Steel Works, St. Petersburg; translated by SERGIUS KERN, M.E. Fcap. 8vo, sewed, 6*d*.

A Treatise on the Origin, Progress, Prevention, and Cure of Dry Rot in Timber; with Remarks on the Means of Preserving Wood from Destruction by Sea-Worms, Beetles, Ants, etc. By THOMAS ALLEN BRITTON, late Surveyor to the Metropolitan Board of Works, etc., etc. *With* 10 *plates*, crown 8vo, cloth, 7*s*. 6*d*.

Metrical Tables. By G. L. MOLESWORTH, M.I.C.E. 32mo, cloth, 1*s*. 6*d*.

CONTENTS.

General—Linear Measures—Square Measures—Cubic Measures—Measures of Capacity—Weights—Combinations—Thermometers.

Elements of Construction for Electro-Magnets. By Count TH. DU MONCEL, Mem. de l'Institut de France. Translated from the French by C. J. WHARTON. Crown 8vo, cloth, 4*s*. 6*d*.

Electro-Telegraphy. By FREDERICK S. BEECHEY, Telegraph Engineer. A Book for Beginners. *Illustrated.* Fcap. 8vo, sewed, 6*d*.

Handrailing: by the Square Cut. By JOHN JONES, Staircase Builder. Part Second, *with eight plates*, 8vo, cloth, 3*s*. 6*d*.

Practical Electrical Units Popularly Explained, with *numerous illustrations* and Remarks. By JAMES SWINBURNE, late of J. W. Swan and Co., Paris, late of Brush-Swan Electric Light Company, U.S.A. 18mo, cloth, 1*s*. 6*d*.

Philipp Reis, Inventor of the Telephone: A Biographical Sketch. With Documentary Testimony, Translations of the Original Papers of the Inventor, &c. By SILVANUS P. THOMPSON, B.A., Dr. Sc., Professor of Experimental Physics in University College, Bristol. *With illustrations*, 8vo, cloth, 7*s*. 6*d*.

A Treatise on the Use of Belting for the Transmission of Power. By J. H. COOPER. Second edition, *illustrated*, 8vo, cloth, 15*s*.

Hints on Architectural Draughtsmanship. By G. W. TUXFORD HALLATT. Fcap. 8vo, cloth, 1*s*. 6*d*.

A Pocket-Book of Useful Formulæ and Memoranda for Civil and Mechanical Engineers. By GUILFORD L. MOLESWORTH, Mem. Inst. C.E., Consulting Engineer to the Government of India for State Railways. *With numerous illustrations*, 744 pp. Twenty-first edition, revised and enlarged, 32mo, roan, 6*s*.

SYNOPSIS OF CONTENTS:

Surveying, Levelling, etc.—Strength and Weight of Materials—Earthwork, Brickwork, Masonry, Arches, etc.—Struts, Columns, Beams, and Trusses—Flooring, Roofing, and Roof Trusses—Girders, Bridges, etc.—Railways and Roads—Hydraulic Formulæ—Canals, Sewers, Waterworks, Docks—Irrigation and Breakwaters—Gas, Ventilation, and Warming—Heat, Light, Colour, and Sound—Gravity: Centres, Forces, and Powers—Millwork, Teeth of Wheels, Shafting, etc.—Workshop Recipes—Sundry Machinery—Animal Power—Steam and the Steam Engine—Water-power, Water-wheels, Turbines, etc.—Wind and Windmills—Steam Navigation, Ship Building, Tonnage, etc.—Gunnery, Projectiles, etc.—Weights, Measures, and Money—Trigonometry, Conic Sections, and Curves—Telegraphy—Mensuration—Tables of Areas and Circumference, and Arcs of Circles—Logarithms, Square and Cube Roots, Powers—Reciprocals, etc.—Useful Numbers—Differential and Integral Calculus—Algebraic Signs—Telegraphic Construction and Formulæ.

Spons' Tables and Memoranda for Engineers; selected and arranged by J. T. HURST, C.E., Author of 'Architectural Surveyors' Handbook,' 'Hurst's Tredgold's Carpentry,' etc. Seventh edition, 64mo, roan, gilt edges, 1*s*.; or in cloth case, 1*s*. 6*d*.

This work is printed in a pearl type, and is so small, measuring only 2½ in. by 1¾ in. by ½ in. thick, that it may be easily carried in the waistcoat pocket.

"It is certainly an extremely rare thing for a reviewer to be called upon to notice a volume measuring but 2½ in. by 1¾ in., yet these dimensions faithfully represent the size of the handy little book before us. The volume—which contains 118 printed pages, besides a few blank pages for memoranda—is, in fact, a true pocket-book, adapted for being carried in the waistcoat pocket, and containing a far greater amount and variety of information than most people would imagine could be compressed into so small a space. . . . The little volume has been compiled with considerable care and judgment, and we can cordially recommend it to our readers as a useful little pocket companion."—*Engineering*.

A Practical Treatise on Natural and Artificial Concrete, its Varieties and Constructive Adaptations. By HENRY REID, Author of the 'Science and Art of the Manufacture of Portland Cement.' New Edition, *with* 59 *woodcuts and* 5 *plates*, 8vo, cloth, 15*s*.

Notes on Concrete and Works in Concrete; especially written to assist those engaged upon Public Works. By JOHN NEWMAN, Assoc. Mem. Inst. C.E., crown 8vo, cloth, 5*s*.

Hydrodynamics: Treatise relative to the Testing of Water-Wheels and Machinery, with various other matters pertaining to Hydrodynamics. By JAMES EMERSON. *With numerous illustrations*, 360 pp. Third edition, crown 8vo, cloth, 4*s*. 6*d*.

Electricity as a Motive Power. By Count TH. DU MONCEL, Membre de l'Institut de France, and FRANK GERALDY, Ingénieur des Ponts et Chaussées. Translated and Edited, with Additions, by C. J. WHARTON, Assoc. Soc. Tel. Eng. and Elec. *With* 113 *engravings and diagrams*, crown 8vo, cloth, 7*s*. 6*d*.

Treatise on Valve-Gears, with special consideration of the Link-Motions of Locomotive Engines. By Dr. GUSTAV ZEUNER, Professor of Applied Mechanics at the Confederated Polytechnikum of Zurich. Translated from the Fourth German Edition, by Professor J. F. KLEIN, Lehigh University, Bethlehem, Pa. *Illustrated*, 8vo, cloth, 12*s*. 6*d*.

The French-Polisher's Manual. By a French-Polisher; containing Timber Staining, Washing, Matching, Improving, Painting, Imitations, Directions for Staining, Sizing, Embodying, Smoothing, Spirit Varnishing, French-Polishing, Directions for Re-polishing. Third edition, royal 32mo, sewed, 6*d*.

Hops, their Cultivation, Commerce, and Uses in various Countries. By P. L. SIMMONDS. Crown 8vo, cloth, 4*s*. 6*d*.

A Practical Treatise on the Manufacture and Distribution of Coal Gas. By WILLIAM RICHARDS. Demy 4to, with *numerous wood engravings and* 29 *plates*, cloth, 28*s*.

SYNOPSIS OF CONTENTS:

Introduction—History of Gas Lighting—Chemistry of Gas Manufacture, by Lewis Thompson, Esq., M.R.C.S.—Coal, with Analyses, by J. Paterson, Lewis Thompson, and G. R. Hislop, Esqrs.—Retorts, Iron and Clay—Retort Setting—Hydraulic Main—Condensers—Exhausters—Washers and Scrubbers—Purifiers—Purification—History of Gas Holder—Tanks, Brick and Stone, Composite, Concrete, Cast-iron, Compound Annular Wrought-iron—Specifications—Gas Holders—Station Meter—Governor—Distribution—Mains—Gas Mathematics, or Formulæ for the Distribution of Gas, by Lewis Thompson, Esq.—Services—Consumers' Meters—Regulators—Burners—Fittings—Photometer—Carburization of Gas—Air Gas and Water Gas—Composition of Coal Gas, by Lewis Thompson, Esq.—Analyses of Gas—Influence of Atmospheric Pressure and Temperature on Gas—Residual Products—Appendix—Description of Retort Settings, Buildings, etc., etc.

Practical Geometry, Perspective, and Engineering Drawing; a Course of Descriptive Geometry adapted to the Requirements of the Engineering Draughtsman, including the determination of cast shadows and Isometric Projection, each chapter being followed by numerous examples; to which are added rules for Shading, Shade-lining, etc., together with practical instructions as to the Lining, Colouring, Printing, and general treatment of Engineering Drawings, with a chapter on drawing Instruments. By GEORGE S. CLARKE, Capt. R.E. Second edition, *with* 21 *plates*. 2 vols., cloth, 10*s*. 6*d*.

The Elements of Graphic Statics. By Professor KARL VON OTT, translated from the German by G. S. CLARKE, Capt. R.E., Instructor in Mechanical Drawing, Royal Indian Engineering College. *With* 93 *illustrations*, crown 8vo, cloth, 5*s*.

The Principles of Graphic Statics. By GEORGE SYDENHAM CLARKE, Capt. Royal Engineers. *With* 112 *illustrations*. 4to, cloth, 12*s*. 6*d*.

Dynamo-Electric Machinery: A Manual for Students of Electro-technics. By SILVANUS P. THOMPSON, B.A., D.Sc., Professor of Experimental Physics in University College, Bristol, etc., etc. Second edition, *illustrated*, 8vo, cloth, 12*s*. 6*d*.

The New Formula for Mean Velocity of Discharge of Rivers and Canals. By W. R. KUTTER. Translated from articles in the 'Cultur-Ingénieur,' by LOWIS D'A. JACKSON, Assoc. Inst. C.E. 8vo, cloth, 12*s*. 6*d*.

Practical Hydraulics; a Series of Rules and Tables for the use of Engineers, etc., etc. By THOMAS BOX. Fifth edition, *numerous plates*, post 8vo, cloth, 5*s*.

A Practical Treatise on the Construction of Horizontal and Vertical Waterwheels, specially designed for the use of operative mechanics. By WILLIAM CULLEN, Millwright and Engineer. *With* 11 *plates*. Second edition, revised and enlarged, small 4to, cloth, 12*s*. 6*d*.

Tin: Describing the Chief Methods of Mining, Dressing and Smelting it abroad; with Notes upon Arsenic, Bismuth and Wolfram. By ARTHUR G. CHARLETON, Mem. American Inst. of Mining Engineers. *With plates*, 8vo, cloth, 12*s*. 6*d*.

Perspective, Explained and Illustrated. By G. S. CLARKE, Capt. R.E. *With illustrations*, 8vo, cloth, 3*s*. 6*d*.

The Essential Elements of Practical Mechanics; based on the Principle of Work, designed for Engineering Students. By OLIVER BYRNE, formerly Professor of Mathematics, College for Civil Engineers. Third edition, *with* 148 *wood engravings*, post 8vo, cloth, 7*s*. 6*d*.

CONTENTS:

Chap. 1. How Work is Measured by a Unit, both with and without reference to a Unit of Time—Chap. 2. The Work of Living Agents, the Influence of Friction, and introduces one of the most beautiful Laws of Motion—Chap. 3. The principles expounded in the first and second chapters are applied to the Motion of Bodies—Chap. 4. The Transmission of Work by simple Machines—Chap. 5. Useful Propositions and Rules.

The Practical Millwright and Engineer's Ready Reckoner; or Tables for finding the diameter and power of cog-wheels, diameter, weight, and power of shafts, diameter and strength of bolts, etc. By THOMAS DIXON. Fourth edition, 12mo, cloth, 3*s*.

Breweries and Maltings: their Arrangement, Construction, Machinery, and Plant. By G. SCAMELL, F.R.I.B.A. Second edition, revised, enlarged, and partly rewritten. By F. COLYER, M.I.C.E., M.I.M.E. *With* 20 *plates*, 8vo, cloth, 18*s*.

A Practical Treatise on the Manufacture of Starch, Glucose, Starch-Sugar, and Dextrine, based on the German of L. Von Wagner, Professor in the Royal Technical School, Buda Pesth, and other authorities. By JULIUS FRANKEL; edited by ROBERT HUTTER, proprietor of the Philadelphia Starch Works. *With* 58 *illustrations*, 344 pp., 8vo, cloth, 18*s*.

A Practical Treatise on Mill-gearing, Wheels, Shafts, Riggers, etc.; for the use of Engineers. By THOMAS BOX. Third edition, *with* 11 *plates*. Crown 8vo, cloth, 7*s.* 6*d.*

Mining Machinery: a Descriptive Treatise on the Machinery, Tools, and other Appliances used in Mining. By G. G. ANDRÉ, F.G.S., Assoc. Inst. C.E., Mem. of the Society of Engineers. Royal 4to, uniform with the Author's Treatise on Coal Mining, containing 182 *plates*, accurately drawn to scale, with descriptive text, in 2 vols., cloth, 3*l.* 12*s.*

CONTENTS:

Machinery for Prospecting, Excavating, Hauling, and Hoisting—Ventilation—Pumping—Treatment of Mineral Products, including Gold and Silver, Copper, Tin, and Lead, Iron Coal, Sulphur, China Clay, Brick Earth, etc.

Tables for Setting out Curves for Railways, Canals, Roads, etc., varying from a radius of five chains to three miles. By A. KENNEDY and R. W. HACKWOOD. *Illustrated*, 32mo, cloth, 2*s.* 6*d.*

The Science and Art of the Manufacture of Portland Cement, with observations on some of its constructive applications. *With* 66 *illustrations*. By HENRY REID, C.E., Author of 'A Practical Treatise on Concrete,' etc., etc. 8vo, cloth, 18*s.*

The Draughtsman's Handbook of Plan and Map Drawing; including instructions for the preparation of Engineering, Architectural, and Mechanical Drawings. *With numerous illustrations in the text, and* 33 *plates* (15 *printed in colours*). By G. G. ANDRÉ, F.G.S., Assoc. Inst. C.E. 4to, cloth, 9*s.*

CONTENTS:

The Drawing Office and its Furnishings—Geometrical Problems—Lines, Dots, and their Combinations—Colours, Shading, Lettering, Bordering, and North Points—Scales—Plotting—Civil Engineers' and Surveyors' Plans—Map Drawing—Mechanical and Architectural Drawing—Copying and Reducing Trigonometrical Formulæ, etc., etc.

The Boiler-maker's and Iron Ship-builder's Companion, comprising a series of original and carefully calculated tables, of the utmost utility to persons interested in the iron trades. By JAMES FODEN, author of 'Mechanical Tables,' etc. Second edition revised, *with illustrations*, crown 8vo, cloth, 5*s.*

Rock Blasting: a Practical Treatise on the means employed in Blasting Rocks for Industrial Purposes. By G. G. ANDRÉ, F.G.S., Assoc. Inst. C.E. *With* 56 *illustrations and* 12 *plates*, 8vo, cloth, 10*s.* 6*d.*

Painting and Painters' Manual: a Book of Facts for Painters and those who Use or Deal in Paint Materials. By C. L. CONDIT and J. SCHELLER. *Illustrated*, 8vo, cloth, 10*s.* 6*d.*

A Treatise on Ropemaking as practised in public and private Rope-yards, with a Description of the Manufacture, Rules, Tables of Weights, etc., adapted to the Trade, Shipping, Mining, Railways, Builders, etc. By R. CHAPMAN, formerly foreman to Messrs. Huddart and Co., Limehouse, and late Master Ropemaker to H.M. Dockyard, Deptford. Second edition, 12mo, cloth, 3*s.*

Laxton's Builders' and Contractors' Tables; for the use of Engineers, Architects, Surveyors, Builders, Land Agents, and others. Bricklayer, containing 22 tables, with nearly 30,000 calculations. 4to, cloth, 5*s.*

Laxton's Builders' and Contractors' Tables. Excavator, Earth, Land, Water, and Gas, containing 53 tables, with nearly 24,000 calculations. 4to, cloth, 5*s.*

Sanitary Engineering: a Guide to the Construction of Works of Sewerage and House Drainage, with Tables for facilitating the calculations of the Engineer. By BALDWIN LATHAM, C.E., M. Inst. C.E., F.G.S., F.M.S., Past-President of the Society of Engineers. Second edition, *with numerous plates and woodcuts*, 8vo, cloth, 1*l.* 10*s.*

Screw Cutting Tables for Engineers and Machinists, giving the values of the different trains of Wheels required to produce Screws of any pitch, calculated by Lord Lindsay, M.P., F.R.S., F.R.A.S., etc. Cloth, oblong, 2*s.*

Screw Cutting Tables, for the use of Mechanical Engineers, showing the proper arrangement of Wheels for cutting the Threads of Screws of any required pitch, with a Table for making the Universal Gas-pipe Threads and Taps. By W. A. MARTIN, Engineer. Second edition, oblong, cloth, 1*s.*, or sewed, 6*d.*

A Treatise on a Practical Method of Designing Slide-Valve Gears by Simple Geometrical Construction, based upon the principles enunciated in Euclid's Elements, and comprising the various forms of Plain Slide-Valve and Expansion Gearing; together with Stephenson's, Gooch's, and Allan's Link-Motions, as applied either to reversing or to variable expansion combinations. By EDWARD J. COWLING WELCH, Memb. Inst. Mechanical Engineers. Crown 8vo, cloth, 6*s.*

Cleaning and Scouring: a Manual for Dyers, Laundresses, and for Domestic Use. By S. CHRISTOPHER. 18mo, sewed, 6*d.*

A Handbook of House Sanitation; for the use of all persons seeking a Healthy Home. A reprint of those portions of Mr. Bailey-Denton's Lectures on Sanitary Engineering, given before the School of Military Engineering, which related to the "Dwelling," enlarged and revised by his Son, E. F. BAILEY-DENTON, C.E., B.A. *With* 140 *illustrations*, 8vo, cloth, 4*s.* 6*d.*

A Glossary of Terms used in Coal Mining. By WILLIAM STUKELEY GRESLEY, Assoc. Mem. Inst. C.E., F.G.S., Member of the North of England Institute of Mining Engineers. *Illustrated with numerous woodcuts and diagrams*, crown 8vo, cloth, 5*s*.

A Pocket-Book for Boiler Makers and Steam Users, comprising a variety of useful information for Employer and Workman, Government Inspectors, Board of Trade Surveyors, Engineers in charge of Works and Slips, Foremen of Manufactories, and the general Steam-using Public. By MAURICE JOHN SEXTON. Second edition, royal 32mo, roan, gilt edges, 5*s*.

Electrolysis: a Practical Treatise on Nickeling, Coppering, Gilding, Silvering, the Refining of Metals, and the treatment of Ores by means of Electricity. By HIPPOLYTE FONTAINE, translated from the French by J. A. BERLY, C.E., Assoc. S.T.E. *With engravings.* 8vo, cloth, 9*s*.

A Practical Treatise on the Steam Engine, containing Plans and Arrangements of Details for Fixed Steam Engines, with Essays on the Principles involved in Design and Construction. By ARTHUR RIGG, Engineer, Member of the Society of Engineers and of the Royal Institution of Great Britain. Demy 4to, *copiously illustrated with woodcuts and* 96 *plates*, in one Volume, half-bound morocco, 2*l*. 2*s*.; or cheaper edition, cloth, 25*s*.

This work is not, in any sense, an elementary treatise, or history of the steam engine, but is intended to describe examples of Fixed Steam Engines without entering into the wide domain of locomotive or marine practice. To this end illustrations will be given of the most recent arrangements of Horizontal, Vertical, Beam, Pumping, Winding, Portable, Semi-portable, Corliss, Allen, Compound, and other similar Engines, by the most eminent Firms in Great Britain and America. The laws relating to the action and precautions to be observed in the construction of the various details, such as Cylinders, Pistons, Piston-rods, Connecting-rods, Cross-heads, Motion-blocks, Eccentrics, Simple, Expansion, Balanced, and Equilibrium Slide-valves, and Valve-gearing will be minutely dealt with. In this connection will be found articles upon the Velocity of Reciprocating Parts and the Mode of Applying the Indicator, Heat and Expansion of Steam Governors, and the like. It is the writer's desire to draw illustrations from every possible source, and give only those rules that present practice deems correct.

Barlow's Tables of Squares, Cubes, Square Roots, Cube Roots, Reciprocals of all Integer Numbers up to 10,000. Post 8vo, cloth, 6*s*.

Camus (M.) Treatise on the Teeth of Wheels, demonstrating the best forms which can be given to them for the purposes of Machinery, such as Mill-work and Clock-work, and the art of finding their numbers. Translated from the French, with details of the present practice of Millwrights, Engine Makers, and other Machinists, by ISAAC HAWKINS. Third edition, *with* 18 *plates*, 8vo, cloth, 5*s*.

A Practical Treatise on the Science of Land and Engineering Surveying, Levelling, Estimating Quantities, etc., with a general description of the several Instruments required for Surveying, Levelling, Plotting, etc. By H. S. MERRETT. Fourth edition, revised by G. W. USILL, Assoc. Mem. Inst. C.E. 41 *plates, with illustrations and tables*, royal 8vo, cloth, 12*s*. 6*d*.

PRINCIPAL CONTENTS:

Part 1. Introduction and the Principles of Geometry. Part 2. Land Surveying; comprising General Observations—The Chain—Offsets Surveying by the Chain only—Surveying Hilly Ground—To Survey an Estate or Parish by the Chain only—Surveying with the Theodolite—Mining and Town Surveying—Railroad Surveying—Mapping—Division and Laying out of Land—Observations on Enclosures—Plane Trigonometry. Part 3. Levelling—Simple and Compound Levelling—The Level Book—Parliamentary Plan and Section—Levelling with a Theodolite—Gradients—Wooden Curves—To Lay out a Railway Curve—Setting out Widths. Part 4. Calculating Quantities generally for Estimates—Cuttings and Embankments—Tunnels—Brickwork—Ironwork—Timber Measuring. Part 5. Description and Use of Instruments in Surveying and Plotting—The Improved Dumpy Level—Troughton's Level—The Prismatic Compass—Proportional Compass—Box Sextant—Vernier—Pantagraph—Merrett's Improved Quadrant—Improved Computation Scale—The Diagonal Scale—Straight Edge and Sector. Part 6. Logarithms of Numbers—Logarithmic Sines and Co-Sines, Tangents and Co-Tangents—Natural Sines and Co-Sines—Tables for Earthwork, for Setting out Curves, and for various Calculations, etc., etc., etc.

Saws: the History, Development, Action, Classification, and Comparison of Saws of all kinds. By ROBERT GRIMSHAW. *With* 220 *illustrations*, 4to, cloth, 12*s*. 6*d*.

A Supplement to the above; containing additional practical matter, more especially relating to the forms of Saw Teeth for special material and conditions, and to the behaviour of Saws under particular conditions. *With* 120 *illustrations*, cloth, 9*s*.

A Guide for the Electric Testing of Telegraph Cables. By Capt. V. HOSKIŒR, Royal Danish Engineers. *With illustrations*, second edition, crown 8vo, cloth, 4*s*. 6*d*.

Laying and Repairing Electric Telegraph Cables. By Capt. V. HOSKIŒR, Royal Danish Engineers. Crown 8vo, cloth, 3*s*. 6*d*.

The Assayer's Manual: an Abridged Treatise on the Docimastic Examination of Ores and Furnace and other Artificial Products. By BRUNO KERL. Translated by W. T. BRANNT. *With* 65 *illustrations*, 8vo, cloth, 12*s*. 6*d*.

The Steam Engine considered as a Heat Engine: a Treatise on the Theory of the Steam Engine, illustrated by Diagrams, Tables, and Examples from Practice. By JAS. H. COTTERILL, M.A., F.R.S., Professor of Applied Mechanics in the Royal Naval College. 8vo, cloth, 12*s*. 6*d*.

Electricity: its Theory, Sources, and Applications. By J. T. SPRAGUE, M.S.T.E. Second edition, revised and enlarged, *with numerous illustrations*, crown 8vo, cloth, 15*s*.

The Practice of Hand Turning in Wood, Ivory, Shell, etc., with Instructions for Turning such Work in Metal as may be required in the Practice of Turning in Wood, Ivory, etc.; also an Appendix on Ornamental Turning. (A book for beginners.) By FRANCIS CAMPIN. Third edition, *with wood engravings*, crown 8vo, cloth, 6*s*.

CONTENTS:

On Lathes—Turning Tools—Turning Wood—Drilling—Screw Cutting—Miscellaneous Apparatus and Processes—Turning Particular Forms—Staining—Polishing—Spinning Metals—Materials—Ornamental Turning, etc.

Health and Comfort in House Building, or Ventilation with Warm Air by Self-Acting Suction Power, with Review of the mode of Calculating the Draught in Hot-Air Flues, and with some actual Experiments. By J. DRYSDALE, M.D., and J. W. HAYWARD, M.D. Second edition, with Supplement, *with plates*, demy 8vo, cloth, 7*s*. 6*d*.

Treatise on Watchwork, Past and Present. By the Rev. H. L. NELTHROPP, M.A., F.S.A. *With 32 illustrations*, crown 8vo, cloth, 6*s*. 6*d*.

CONTENTS:

Definitions of Words and Terms used in Watchwork—Tools—Time—Historical Summary—On Calculations of the Numbers for Wheels and Pinions; their Proportional Sizes, Trains, etc.—Of Dial Wheels, or Motion Work—Length of Time of Going without Winding up—The Verge—The Horizontal—The Duplex—The Lever—The Chronometer—Repeating Watches—Keyless Watches—The Pendulum, or Spiral Spring—Compensation—Jewelling of Pivot Holes—Clerkenwell—Fallacies of the Trade—Incapacity of Workmen—How to Choose and Use a Watch, etc.

Notes in Mechanical Engineering. Compiled principally for the use of the Students attending the Classes on this subject at the City of London College. By HENRY ADAMS, Mem. Inst. M.E., Mem. Inst. C.E., Mem. Soc. of Engineers. Crown 8vo, cloth, 2*s*. 6*d*.

Algebra Self-Taught. By W. P. HIGGS, M.A., D.Sc., LL.D., Assoc. Inst. C.E., Author of 'A Handbook of the Differential Calculus,' etc. Second edition, crown 8vo, cloth, 2*s*. 6*d*.

CONTENTS:

Symbols and the Signs of Operation—The Equation and the Unknown Quantity—Positive and Negative Quantities—Multiplication—Involution—Exponents—Negative Exponents—Roots, and the Use of Exponents as Logarithms—Logarithms—Tables of Logarithms and Proportionate Parts—Transformation of System of Logarithms—Common Uses of Common Logarithms—Compound Multiplication and the Binomial Theorem—Division, Fractions, and Ratio—Continued Proportion—The Series and the Summation of the Series—Limit of Series—Square and Cube Roots—Equations—List of Formulæ, etc.

Spons' Dictionary of Engineering, Civil, Mechanical, Military, and Naval; with technical terms in French, German, Italian, and Spanish, 3100 pp., and *nearly* 8000 *engravings*, in super-royal 8vo, in 8 divisions, 5*l*. 8*s*. Complete in 3 vols., cloth, 5*l*. 5*s*. Bound in superior manner, half-morocco, top edge gilt, 3 vols., 6*l*. 12*s*.

Canoe and Boat Building: a complete Manual for Amateurs, containing plain and comprehensive directions for the construction of Canoes, Rowing and Sailing Boats, and Hunting Craft. By W. P. STEPHENS. *With numerous illustrations and 24 plates of Working Drawings.* Crown 8vo, cloth, 7*s*. 6*d*.

Cultural Industries for Queensland: Papers on the cultivation of useful Plants suited to the climate of Queensland, their value as Food, in the Arts, and in Medicine, and methods of obtaining their products. By L. A. BERNAYS, F.L.S., F.R.G.S. 8vo, half calf, 7*s*. 6*d*. The same, in cloth, 6*s*.

Proceedings of the National Conference of Electricians, Philadelphia, October 8th to 13th, 1884. 18mo, cloth, 3*s*.

Dynamo-Electricity, its Generation, Application, Transmission, Storage, and Measurement. By G. B. PRESCOTT. *With 545 illustrations.* 8vo, cloth, 1*l*. 1*s*.

Domestic Electricity for Amateurs. Translated from the French of E. HOSPITALIER, Editor of "L'Electricien," by C. J. WHARTON, Assoc. Soc. Tel. Eng. *Numerous illustrations.* Demy 8vo, cloth, 9*s*.

CONTENTS:

1. Production of the Electric Current—2. Electric Bells—3. Automatic Alarms—4. Domestic Telephones—5. Electric Clocks—6. Electric Lighters—7. Domestic Electric Lighting—8. Domestic Application of the Electric Light—9. Electric Motors—10. Electrical Locomotion—11. Electrotyping, Plating, and Gilding—12. Electric Recreations—13. Various applications—Workshop of the Electrician.

Wrinkles in Electric Lighting. By VINCENT STEPHEN. *With illustrations.* 18mo, cloth, 2*s*. 6*d*.

CONTENTS:

1. The Electric Current and its production by Chemical means—2. Production of Electric Currents by Mechanical means—3. Dynamo-Electric Machines—4. Electric Lamps—5. Lead—6. Ship Lighting.

The Practical Flax Spinner; being a Description of the Growth, Manipulation, and Spinning of Flax and Tow. By LESLIE C. MARSHALL, of Belfast. *With illustrations.* 8vo, cloth, 15*s*.

Foundations and Foundation Walls for all classes of Buildings, Pile Driving, Building Stones and Bricks, Pier and Wall construction, Mortars, Limes, Cements, Concretes, Stuccos, &c. 64 *illustrations.* By G. T. POWELL and F. BAUMAN. 8vo, cloth, 10*s*. 6*d*.

Manual for Gas Engineering Students. By D. LEE. 18mo, cloth 1*s*.

Hydraulic Machinery, Past and Present. A Lecture delivered to the London and Suburban Railway Officials' Association. By H. ADAMS, Mem. Inst. C.E. *Folding plate.* 8vo, sewed, 1*s*.

Twenty Years with the Indicator. By THOMAS PRAY, Jun., C.E., M.E., Member of the American Society of Civil Engineers. 2 vols., royal 8vo, cloth, 12*s*. 6*d*.

Annual Statistical Report of the Secretary to the Members of the Iron and Steel Association on the Home and Foreign Iron and Steel Industries in 1884. Issued March 1885. 8vo, sewed, 5*s*.

Bad Drains, and How to Test them; with Notes on the Ventilation of Sewers, Drains, and Sanitary Fittings, and the Origin and Transmission of Zymotic Disease. By R. HARRIS REEVES. Crown 8vo, cloth, 3*s*. 6*d*.

Standard Practical Plumbing; being a complete Encyclopædia for Practical Plumbers and Guide for Architects, Builders, Gas Fitters, Hot-water Fitters, Ironmongers, Lead Burners, Sanitary Engineers, Zinc Workers, &c. *Illustrated by over* 2000 *engravings.* By P. J. DAVIES. Vol. 1, royal 8vo, cloth, 7*s*. 6*d*.

Pneumatic Transmission of Messages and Parcels between Paris and London, viâ Calais and Dover. By J. B. BERLIER, C.E. Small folio, sewed, 6*d*.

List of Tests (Reagents), arranged in alphabetical order, according to the names of the originators. Designed especially for the convenient reference of Chemists, Pharmacists, and Scientists. By HANS M. WILDER. Crown 8vo, cloth, 4*s*. 6*d*.

Ten Years' Experience in Works of Intermittent Downward Filtration. By J. BAILEY DENTON, Mem. Inst. C.E. Second edition, with additions. Royal 8vo, sewed, 4*s*.

A Treatise on the Manufacture of Soap and Candles, Lubricants and Glycerin. By W. LANT CARPENTER, B.A., B.Sc. (late of Messrs. C. Thomas and Brothers, Bristol). *With illustrations.* Crown 8vo, cloth, 10*s*. 6*d*.

The Stability of Ships explained simply, and calculated by a new Graphic method. By J. C. SPENCE, M.I.N.A. 4to, sewed, 3*s*. 6*d*.

Steam Making, or Boiler Practice. By CHARLES A. SMITH, C.E. 8vo, cloth, 10*s*. 6*d*.

CONTENTS:

1. The Nature of Heat and the Properties of Steam—2. Combustion.—3. Externally Fired Stationary Boilers—4. Internally Fired Stationary Boilers—5. Internally Fired Portable Locomotive and Marine Boilers—6. Design, Construction, and Strength of Boilers—7. Proportions of Heating Surface, Economic Evaporation, Explosions—8. Miscellaneous Boilers, Choice of Boiler Fittings and Appurtenances.

The Fireman's Guide; a Handbook on the Care of Boilers. By TEKNOLOG, föreningen T. I. Stockholm. Translated from the third edition, and revised by KARL P. DAHLSTROM, M.E. Second edition. Fcap. 8vo, cloth, 2*s*.

A Treatise on Modern Steam Engines and Boilers, including Land Locomotive, and Marine Engines and Boilers, for the use of Students. By FREDERICK COLYER, M. Inst. C.E., Mem. Inst. M.E. *With* 36 *plates.* 4to, cloth, 25*s*.

CONTENTS:

1. Introduction—2. Original Engines—3. Boilers—4. High-Pressure Beam Engines—5. Cornish Beam Engines—6. Horizontal Engines—7. Oscillating Engines—8. Vertical High-Pressure Engines—9. Special Engines—10. Portable Engines—11. Locomotive Engines—12. Marine Engines

Steam Engine Management; a Treatise on the Working and Management of Steam Boilers. By F. COLYER, M. Inst. C.E., Mem. Inst. M.E. 18mo, cloth, 2*s*.

Land Surveying on the Meridian and Perpendicular System. By WILLIAM PENMAN, C.E. 8vo, cloth, 8*s*. 6*d*.

The Topographer, his Instruments and Methods, designed for the use of Students, Amateur Photographers, Surveyors, Engineers, and all persons interested in the location and construction of works based upon Topography. *Illustrated with numerous plates, maps, and engravings.* By LEWIS M. HAUPT, A.M. 8vo, cloth, 18*s*.

A Text-Book of Tanning, embracing the Preparation of all kinds of Leather. By HARRY R. PROCTOR, F.C.S., of Low Lights Tanneries. *With illustrations.* Crown 8vo, cloth, 10*s*. 6*d*.