commercial demand for such uses were not sufficient, the cultivation for paper stuff, at once, might prove remunerative.

Fibrous plants not necessarily an exhausting crop.—In this connection we must mention one important matter relating to the culture of fibrous plants, many of which are supposed to exhaust the soil in a peculiar manner. It is true that such plants do often withdraw from the soil a large portion of soluble inorganic matter, which, if the crop were wholly carried off, would soon leave the soil incapable of sustaining a future crop of the same plant. But the fiber itself contains only a small percentage of these ingredients, which are directly measured by the ash. This is found in greatest quantity in the refuse of the crop. If, then, the rotting is done upon the same field which produced the plant, many of the soluble matters are at once restored to the soil from which they had been drawn. The leaves fall upon the ground, and carry back other mineral ingredients, and finally the refuse, after breaking, restores most of the remainder. Hence, if the ashes of the refuse are returned to the soil, there is but little left which must artificially be added to restore its original condition. These relations of the fiber to the plant from which it is drawn are too little known, and yet a want of such knowledge is frequently the cause of wholly unnecessary exhaustion of the soil.

Structure of bast cells.—We have given no minute account of the characters of bast, as the varieties are almost endless. As a general rule, the cell-walls are rather thick, showing the spiral structure, while the cells are longer than in any other vegetable tissue, and, in some cases, are not simple, but more or less branching. The thickened walls are scarcely ever filled with the rigid, incrusting matter found in the wood-cells of the stem; hence the greater pliability of the bast. The bundles of fiber in their section, although commonly wedge-shaped, are sometimes semi-cylindrical, but the intervention of rows of pith-cells, which disappear in preparing the fiber, in most instances leaves the bast in flat ribbons. All of these peculiarities may, at once, be readily determined by a microscopic examination, aided by the proper chemical tests.

We have said but little of the wood of exogens, because it rarely furnishes a useful fiber, except for the purpose of paper-making, upon which we are about to make a few remarks.

Cotton, structure of the cell.—Cotton we have only mentioned incidentally, because it does not form a constituent of any of the tissues which we have described, being made up, as has been stated, of the hairs, each one a single cell upon the seeds of the plant. The great value of cotton, and that which distinguishes it from all known hairs of plants, is the spiral structure of the cell-wall, recognized not only in the finer markings upon the fiber, but by the form of the entire cell, which may best be represented as a tube flattened until the opposite sides nearly or quite meet, but with this flattening not in one place, but in a spiral direction. Every degree of twist may be found in cotton, some fibers being scarcely more than ribbons, while others are very well described as screws. Upon this character, combined with the fineness and length of the cells, the value of the fiber mainly depends. In previous articles in the Patent Office Reports we have furnished information upon this subject, but much yet remains to be determined, which can only be done after a more careful study of a great variety of specimens, and under favorable circumstances, which have not yet occurred to any one capable of such an investigation.

FIBROUS MATERIALS FOR PAPER.

Historical notice.—The complaint that rags alone were not sufficient to supply the wants of the paper-maker dates back at least one hundred years; and that this complaint has not been without foundation is shown by the constant increase in the price of rags. Improvements in the process of manufacture, and the introduction of new material, have, at intervals, delayed this increase in price, but only for a short time. The demand for new material for paper-making has led to many investigations, the most remarkable of which are those detailed in the work of Dr. J. C. Schaeffer, before mentioned. This book is illustrated by a large number of specimens of paper made from different substances in the house of the author. In making his paper the old-fashioned pounding machine was used, and the material was only reduced to the condition of "half stuff," the specimens are therefore rather coarse. Chlorine, our great modern bleaching agent, being unknown at that time, the paper presents the natural hue of the material. In many of the specimens there is a mixture with rags, but some of the most curious have no such addition. The leaves, stems, and hairs of various plants, moss, algæ, shavings and saw-dust of woods of different kinds, wasp-nests, old shingles, potato peelings, and apparently every accessible source of vegetable fiber, were experimented upon, and specimens of the paper furnished; in one case the mineral kingdom is made to contribute paper from asbestus.

The publication of this work seems to have given some stimulus to this new branch of industry, and new materials have gradually come into use. The process of bleaching by chlorine, or its compounds, gave a new impetus, as it brought into use serviceable fibers which, from their color, had previously been inapplicable to the manufacture of white paper. From time to time other works with specimens have appeared, but the modes of treatment were essentially the same as those introduced about the end of the last century, and these, we have already shown, with the exception of bleaching by chlorine, had been known for centuries in the East. The latest work of consequence, with actual specimens, was published by L. Piette in 1838.

Piette mainly confines himself to straw; but, making use of chemical agents, he has produced paper of superior quality. The specimens are particularly valuable, as they show, not only paper from each material unmixed, but from various intermixtures of the materials with each other and with rags. A very slight examination of Piette's specimens will be enough to satisfy any one that good, strong, white, and smooth paper may be made of straw, the productions of the different kinds, however, having peculiarities. The author does not seem to have a very high opinion of paper made from wood, and gives, as a specimen of the best mode of using this material, a very neat *shaving* which, at first sight, looks like a delicately tinted paper. Strange as

Piette's suggestions may appear, we have in our collection a very elegant visiting card, printed in Paris, not upon paper, but upon a thin and uniform shaving of wood. This use of wood seems destined to extend the meaning of the word "shingle," from the sign to the card.*

As an evidence of the supply of paper stuff from other substances than rags, as far as Europe is concerned, we may state, from good authority, that single establishments use for such purpose straw, wood, or even stable manures to the extent of hundreds of tons annually.

The manufacture of paper from straw, wood, &c., in the United States, originated between 1828 and 1830. The first article made, in any quantity, was a coarse and rather brittle wrapping-paper, from straw, but an article from wood, good enough to use for newspapers, was made about the same time. This branch of industry has, however, made but little progress, except for coarser purposes, although fair white paper has been made from both straw and wood. It is to be remarked that waste rope and bagging, and fibers of all kinds, enter largely into the manufacture of the best kinds of paper; the modes of treatment in all cases being essentially the same, the source of supply being determined by the cost.

Condition of fiber, as found in paper.—Although the manufacture of paper from various materials has, so far as the processes are concerned, attained a high state of advancement, the minute study of the condition of the fiber in paper seems to have received scarcely any attention until a quite recent date. So far as we can learn, the first investigation on this subject was announced by Reissek, in a communication to the Royal Academy of Sciences in Vienna, in 1845, but not published until 1852. This article is illustrated by several figures, which correctly represent fiber, mainly flax, as found in papers of different qualities. In the next year Schacht published a work, in which the fiber from paper made of various materials is well illustrated. From these drawings, and from the descriptions of the authors, it is easy to understand the condition to which paper stuff must be reduced, and if our previous account of the structure of the vegetable cell is remembered, we may, in a few words, convey a correct idea of the nature and condition of the fiber in paper, even without the aid of drawings.

It will not be necessary, in this place, to describe the engine by which rags, &c., are reduced to pulp for paper; it is sufficient to say that by its action the fiber is *broken*, not *cut*, into fragments, the length of which is but a very small fraction of an inch. If the fiber could be divided by a clean cut, no paper could be made from the resulting pulp, for it is the rough and jagged ends of the fragments which give the peculiar felting property to ordinary paper stuff. Instead of "fiber," in this paragraph, we might rather have said "cells," for, in reality, the peculiar kind of fracture of which we have been speaking depends upon the breaking up of the cells; a mere separation of the cells from each other would give, as must be evident, but a useless product. The material introduced into the engine is, with few exceptions, a compound fiber, and as there is not a perfect separation of the cells laterally, however much they may be broken in their length, we have used the word "fiber" advisedly.

* Since this was written we have learned that "chip" cards have been introduced into the United States, and are now on sale at the stores.

If the walls of the cell were of uniform thickness, there would be no reason why they should break with any other than an even and nearly transverse fracture; but if we remember the constant tendency to a spiral direction in the thickening of the cell wall, we can readily understand that the operation of the paper engine will be to *fray* the broken ends of the cells into strips, which will take a more or less spiral direction, when they are free to take the most natural position. The paper pulp being suspended in water, having nearly its own specific gravity, these frayed ends will readily resume the original turn or twist which they had as thickened portions of the cell wall. Hence the felting property of paper stuff, which, by the intertwining of even the smallest fragments of a cell, allows the whole mass, on drying, to form a continuous and coherent sheet. The introduction of size, as a matter of course, increases the cohesion, but a consideration of this part of paper manufacture, and its further consequences, would lead us beyond our limits.

We have spoken of the cells as broken, but it must be evident, from the variety of directions in which they are presented to the beating surfaces in the engine, that they are often split; but this does not alter the condition of things, for the direction of the split will be the same with that of the frayed ends. The interlacing properties, derived from the character of the outside surface of the cell, need not be insisted upon here, since we have already said enough upon this point.

The fineness and smoothness of the paper from any given material depends upon the degree of comminution of the fiber, which may be carried so far as to leave nothing but split and frayed fragments, scarcely a single cell retaining its original diameter. The strength of the paper, of course, diminishes with such a treatment, a fine and yet strong fabric being only produced by a due mixture of portions of fibre representing the two extremes of subdivision. The best condition would be attained when each fragment, as far as possible, exemplified the two extremes—that is, when portions of cells, retaining their original diameter, would be furnished with a long and abundant fringe of frayed ends. The experience and skill of the paper-maker has, in a general way, led to the attainment of desired results, with old and well-known material, but this has been done in ignorance of the precise conditions upon which these results depend, and for any new material, time and expense only can be employed, to acquire an equally good skill and experience. But by a knowledge of the precise character of the material, obtained from microscopic examination, and by the aid of a few reagents, a sound basis may be laid for intelligent experiment, with a saving of both time and trouble.

Microscopic examination of wood for paper stuff.—As an illustration of our assertion, let us suppose that a certain wood is proposed as a material for the paper-maker. The thinnest possible cross section is examined under the microscope, and the figure as well as the thickness of the wood cells, noted. The specimen is next treated with solution of iodine, and then with chloride of zinc, or dilute sulphuric acid, and again observed. The portions colored blue will show how much of the cell wall retains its original character, and those which are reddish-brown show the infiltration and deposit of the incrusting matter. A similar section is next to be treated in the same way, after having been boiled in a solution of caustic potash, or soda. The increased portion colored blue and the diminution of the red will show how much of the useless incrusting matter has been removed, and by repeating the experiment we can soon obtain an approximate estimation of the amount of and the cost of removing the useless ingredients. We can also obtain a correct idea of the outline of the section of the individual cells, whether angular, rounded, or ribbed, points which we have before shown are of no little value. A small portion of a very thin shaving of the wood, in a longitudinal direction, is, after boiling in an alkaline solution, again examined. If the cells are not well separated, we may resort to some of the more powerful reagents, or if the shaving is, microscopically speaking, thin enough, we may use needles to tear the cells apart. We then observe the length of the individual cells, and, above all, the markings upon them, which show the uniformity or spiral arrangement of the thickened portions. We are then prepared to give, in accordance with what has been said above, a good approximate estimate of the value of the wood as a material for paper-making.

We have selected wood as an illustration, because we have not, as yet, particularly described its structure, and because two important points, the length of the cells and the quantity of incrusting matter, are brought under consideration. Almost any substance, otherwise useful as fiber, may be converted into paper, yet the relative values of different materials may be determined by the methods above described.

Structure of wood cells.—As a general rule, the cells of wood are short, with pointed ends, and may sometimes be even too short for paper stuff. Interspersed among the true wood cells, we always find the ducts, described above, with the single exception of the pine family, which may always be recognized by the "disks," with a "pore" in their center, found generally on the radial surface of the cells. In the *Coniferæ*, or pines, we often find an abundance of resin; this, like the incrusting matter, must be removed by an alkaline solution.

In the Pine family, which most largely contributes wood for the manufacture of paper, we find notable differences in the character of the cells, and are thus able, even in fossil woods, to determine the exact character of the plant. Without any trial, we can say that the yew (*Taxus*,) and its ally *Torreya*, would furnish a material for paper, with peculiar properties, derived from the remarkable spiral thickening of the cells. Unfortunately, trees of these genera are not abundant enough to warrant even an experimental examination.

In some woods, in addition to the medullary rays, made up of what we have called pith cells, there is another tissue of similar cells, which cannot be expected to add to the strength of paper stuff.

Economy of using wood for paper stuff.—It is, therefore, easy to determine what sort of wood is best adapted to paper-making, and we have in our collection specimens which show that the range of choice is by no means limited. But another question of economy arises, which has excited much inquiry and invention, namely, the most advantageous method of reducing solid wood to the requisite degree of fineness, for subsequent treatment. A good rule, equally applicable to the manures of the farmer and to the supply of the paper-making material, we would give in a few words: *use what others waste*. If the thousands of tons of saw-dust, annually wasted at the different saw-mills in the country, could be collected in one place, there would be no want of material for paper of a certain quality. But as this cannot be done, we may fairly suppose that, in some localities, an abundant supply may be maintained; if not, resort must be had, provided that the wood itself is cheap enough, to mechanical means of disintegration, which are beyond the bounds of our present inquiry.

When grass, straw, or herbaceous plants are used for making paper, a new matter for consideration arises. The great abundance of pith cells in these is wholly, or in part, removed, and passes off as waste, either in the treatment with alkaline solutions, or from the paper engine. The exact weight of solid matter in such materials cannot, therefore, be reproduced as paper, and the loss must be accompanied by a corresponding cost in the process which causes the loss. In such cases, again, a microscopical examination of the material may afford an approximate estimate of its value.

We would like, in this connection, to refer to a process of paper-making in some respects quite different from that which is used among us, yet in the East has made paper a substitute for cloth and for other fabrics, which we manufacture at a great cost. But, without space to describe even the specimens illustrative of this point, we must, for the present, abstain from entering upon new matter.

In conclusion, we have to say that the foregoing is to be regarded as the mere outline or sketch of the research of several years, which might, if expanded into details, have filled a goodly volume. Our endeavor has been to give a general view of the subject, trusting it may prove interesting, and even profitable, to the reader, furnishing at the same time sufficient indications of the course to be pursued if he should be desirous of further information.

In general, we have abstained from quoting authorities as out of place in an article of this kind. But no statement has been made which cannot be substantiated by sufficient authority, or by our own demonstration. Considered as a mere sketch of what might have been said, we must beg those who are well informed upon any one particular point to remember that, if we had noticed everything by the way, our article would have increased to a volume, and to believe that the omissions which may be criticised by them are regretted by us.

IMPORTANCE OF SALT IN AGRICULTURE.

If we should ask why so enormous a quantity of this inestimable gift of salt is distributed throughout the earth; why three fourths of the surface of the planet designed for the home of man is covered with