On the Structure of an Ancient Paper¹.

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IN November last, Professor Marshall Ward handed to me a specimen of ancient paper, with the request that I should attempt to determine the botanical nature of the materials of which it was made.

Examined macroscopically, the paper may be described as a light-brown felt-like substance, consisting of layers—easily separable one from the other—of closely interwoven fibres.

¹ The paper here referred to was one of four pieces of ancient MSS. which were sent to me by Mrs. Gibson of Castle Brae, Cambridge, for examination as to the materials of which they were composed. These MSS. are parts of a series discovered by Mrs. Gibson and Mrs. Lewis at Cairo in 1897, and which proved of some historical interest. They almost certainly came from the Genizeh or lumber-room of the Synagogue in Old Cairo, whose contents Mr. Schechter has brought to Cambridge. The writing on them is Hebrew, and refers to legal matters. Mrs. Gibson informs me that on one fragment there is conclusive evidence of the date, 1038, and further inquiry leads to the conviction that this is one of the oldest fragments of such writing in England. I subsequently received by Mr. Schechter's kindness another fragment of a similar paper. On testing these five papers I found them to be made of flax or some similar fibre, and the subject seemed so interesting that I asked Miss Dawson to go more fully into the matter, which she has successfully done.—H. MARSHALL WARD.

As is well known, many ancient writings are on vellum or papyrus: this, however, was evidently neither a prepared animal skin nor so complicated a tissue as that of the *Cyperus Papyrus*. It clearly was composed of fibres which had by some process been extracted from the tissues of some plant.

After teasing in water and examining with the microscope, the paper was seen to consist of fibres, often occurring in strands, accompanied by elements showing spiral or simple-pitted markings, and here and there by cells of wood-parenchyma or medullary rays. The layers of the paper appear to have been stuck, not woven together; an examination of the dust, shattered from the paper, showed, after treatment with iodine, yellow and bluish-black particles—the latter sometimes lying along the fibres, and giving to them a blue colour. This suggested that some form of starch may have been used in the manufacture, but all attempts to determine its nature were unsuccessful. This alteration of the starch-grains, which had evidently taken place, was probably due to the action of numerous Fungus-hyphae, and groups of Bacteria-like bodies, which could be seen amongst the fibres.

The individual fibres are somewhat cylindrical in shape, with pointed ends, and very narrow lumen. Their walls are thick, and show regular longitudinal striations, but no visible pits. Their breadth is practically constant ($\cdot 015$ mm.), but the length varies considerably: the extreme measurements taken were 6.4 mm. and 3.1 mm.; an average of ten measurements gave 4.25 mm. As, however, so many of the fibres were broken, accurate measurements of length were not possible, and these figures cannot be relied upon. It can, nevertheless, be affirmed that the fibres are shorter and narrower than those of cotton, and are not, like them, flattened and twisted.

They show a marked tendency to tear into fibrillae, often in spirals, and show traces of swellings or kinks. With Schulze's solution, they give a purple colour, with iodine pink, and with iodine and sulphuric acid blue: but no trace of

lignin-reaction can be obtained either with phloroglucin and HCl or with aniline sulphate.

When treated with Cu. Amm., the fibres behave in a characteristic manner: the walls swell greatly—causing the striations to become beautifully clear—and the lumen persists for some time as a very narrow, dark, wavy line, running down the middle. The above results lead to the conclusion that they are some sort of non-lignified bast-fibres.

Among the fibres which seemed likely to be met with as ancient paper-materials are Flax, Hemp, *Boehmeria*, *Broussonetia*, Cotton, and Nettle¹. We may exclude, by the reactions, such lignified fibres as jute, straw, and wood, met with in modern papers: and, probably, certain Indian and out-of-the-way fibres, as Rice, Bamboo, Daphne, New Zealand Flax, &c., may also be neglected.

A careful examination of the above list gave the following results²:—

1. *Cotton* fibres are flat and often twisted; they are broader, longer, and show a wider lumen than those under investigation; and in addition, when treated with Cu. Amm. they coil into spirals before complete solution.
2. *Nettle* (*Urtica dioica*) fibres, like those of cotton, are flat, and somewhat twisted; they are even broader than those of Cotton, and show as wide a lumen. Their walls have distinct longitudinal and transverse striations, and under the action of Cu. Amm. they become swollen and much crumpled, leaving the broad lumen very clearly visible.
3. *Boehmeria nivea* fibres resemble the fibres of the paper in their breadth, narrow lumen, and non-lignified walls, but are clearly distinguished from them by their club-shaped ends, and their characteristic behaviour with Cu. Amm., viz. rapidly coiling into loose spirals.

¹ J. Wiesner, Die Rohstoffe des Pflanzenreiches, p. 447.

² See also Cross and Bevan, A Text-book of Paper-making, pp. 30-61.

4. *Hemp* (*Cannabis sativa*) fibres are long and narrow, with a very narrow lumen. Their ends, however, are slightly flattened, and their micro-chemical reactions distinguish them from the fibres of which the paper is made: thus they give a yellowish colour with aniline sulphate, green with iodine and H_2SO_4 , and in Cu. Amm. they swell greatly, showing longitudinal striations, with a comparatively broad central wavy line.
5. *Flax* (*Linum perenne*) fibres are long and narrow, the walls are thick and non-lignified, and show characteristic swellings or kinks, where fibres have crossed one another. Their behaviour, under the action of Cu. Amm., is strictly comparable to that of the fibres of the paper. The chemical reaction of the walls also agrees closely in the two cases.

A comparison of the above results shows at once that we must exclude the fibres of Cotton, Nettle, *Boehmeria*, and Hemp. I was unable to examine those of *Broussonetia*, but Wiesner's¹ description of them puts them also on one side.

On the contrary, the shape, narrow lumen, and pointed ends, the chemical properties of the walls, their reaction with cupric ammonia, longitudinal striations, tendency to fray into fibrillae, and the traces of slight swellings or kinks, all point to the conclusion that we are dealing with bast-fibres of *Flax*.

Considering the subject from a historical standpoint, we learn from De Candolle² that Flax was familiar to the Chaldeans, Egyptians, and Hebrews. The plant figures in Egyptian drawings, and, as the microscope has revealed, the bandages, used as mummy-wrappings, were made of linen. Moreover, the annual Flax was cultivated for thousands of years in Mesopotamia, Assyria, and Egypt, and it was, and still is, found wild in the districts lying between the Persian Gulf and the Caspian and Black Seas.

¹ J. Wiesner, *Die Rohstoffe des Pflanzenreiches*, p. 459.

² De Candolle, *Origin of Cultivated Plants*, 1884, pp. 123-130.

It is interesting to note also, that Karabacek, in his preface to the descriptive catalogue of the Archduke Rainer's Collection of MSS.¹, gives reasons for concluding that the Arabs learnt the art of paper-making from plant-fibres, from the Chinese, about A.D. 751.

We are not, therefore, guilty of any anachronism in assuming that, by the year 1038—the date which has been assigned to this paper—the process of manufacturing paper from the fibres of the Flax-plant was both known and employed.

¹ Führer durch die Ausstellung Papyrus des Herzog Rainer, 1892, Th. I, pp. xvii-xxiv.

Dawson, M. 1898. "On the structure of an ancient paper." *Annals of botany* 12, 111–115. <https://doi.org/10.1093/oxfordjournals.aob.a088679>.

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