surface-swimming, fish, M.S. *Warreen* (a native name for the sea) was built in Melbourne and has been in commission for about fifteen months. She is 82 ft. long, of 108 tons displacement, and is fitted with a 215 h.p. main engine of Atlas Polar Diesel construction, with Ruston auxiliaries. She carries radio equipment for transmitting and receiving, and an echometer for automatic recording of depth. A small laboratory permits limited work at sea. A large purse-seine net is carried on a turn-table in the stern.

Over so great an extent of sea, one small vessel capable of a speed of only 9 knots can do but little: hence very full use is being made of reconnaissance from the air. Aircraft and personnel are made available to the Council by the Royal Australian Air Force; and particularly in the 'spotting' of shoals of tuna and so-called salmon (*Arripis trutta*), air observation has been conspicuously successful. Already possibilities have been demonstrated which are attracting the attention of commercial men; but a great amount of scientific investigation will be necessary before a sound basis for fisheries development is secured.

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# STRUCTURE OF THE RAYON FIBRE

## BY PROF. H. MARK

REFERENCE has frequently been made in these columns[1] to the progress of our knowledge concerning the structure of natural and artificial fibres during the last few years. The accompanying illustration (p. 314) gives a résumé of the present state of knowledge as represented by the cellulose fibre, which is very well known and at the same time of great economic importance.

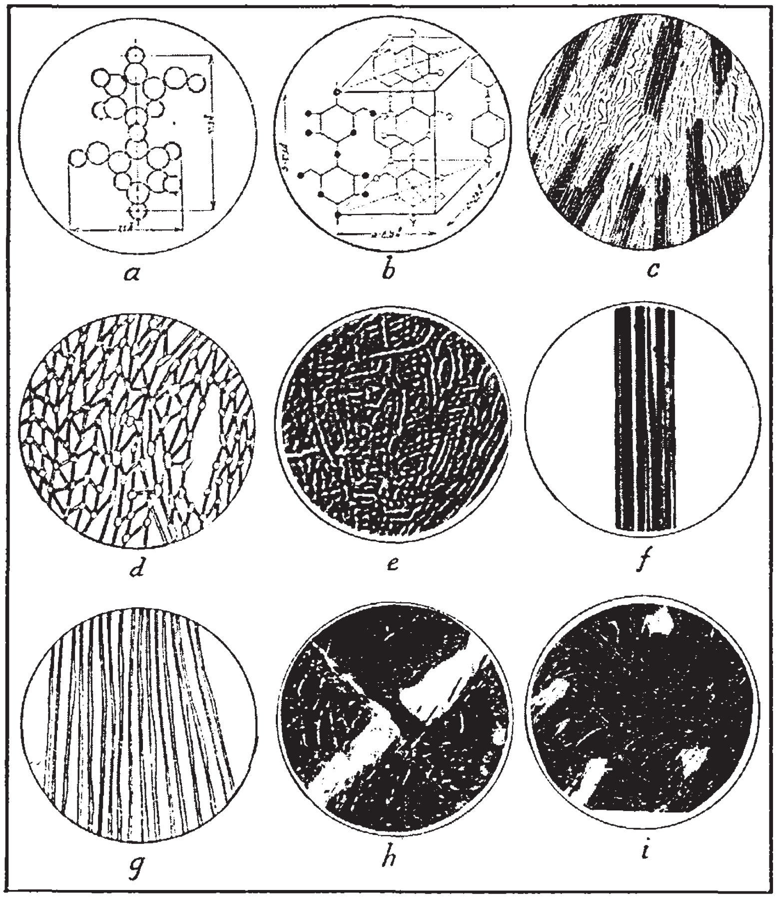
The illustration was made up under the assumption that we have at our disposal a microscope allowing us magnifications of unlimited amounts in such a way that we can always increase its resolving power by the factor of 10 by switching in another imaginary objective. Looking at a rayon thread through such a microscope, we should obtain such a series of pictures, and it seems desirable to discuss them one after the other and to point out what kind of information they give and to what extent the particular qualities of the fibre are shown by them.

(*a*) We start with the highest magnification, about 1 to 50,000,000, and observe the *fundamental chemical unit* of cellulose, namely, the *glucose residue* composed of 6 carbon atoms, 10 hydrogen atoms and 5 oxygen atoms[2]. These glucose units have a ring structure and are linked together by main valence bonds. They stand for the chemical behaviour of the material, for example, for the fact that cellulose is easily wetted and swells in water, but does not take up organic substances such as petrol, benzene or oil. They are also responsible for the fact that one can produce certain derivatives of cellulose, namely, cellulose nitrate (celluloid), cellulose acetate (cellon), etc. Finally their presence is responsible for the fact that by hydrolysis cellulose can be converted into a sugar.

(*b*) We pass now to the next magnification, 1 to 5,000,000, and get an insight into the *crystallographic unit* of the fibre. What we see is the *elementary cell* of the cellulose lattice revealed by X-ray investigations[3]. We see that the different glucose residues are united to long chains lying parallel to each other and running through the fibre along its axis. The presence of these long and highly orientated chains explains the double refraction of the material, its high mechanical tenacity, the anisotropy in swelling and the behaviour towards substantive dye-stuffs.

(*c*) When we switch in a magnification of 1 to 500,000 we get the next picture. Here each single chain of diagram *b* is represented by a thin line. We learn that these chains are partly bundled together with a considerable degree of order forming a *micellar structure*, and partly they represent a complicated framework of entangled fringes. We get the impression that the whole fibre consists of parts with comparatively high crystallographic orientation and of other parts which can be called amorphous. This peculiar structure accounts for the fact that rayon fibres at the same time show a considerable strength and a high elasticity. It is responsible for the amount of swelling, the dyeability, and the resistance to creasing. Every process that aims at producing rayon has to take account of this fact.

(*d*) The next step, leading to a magnification of 1 to 50,000, gives a more general view of this *fringe and net structure* of cellulose. In *d* the parallel strokes represent the crystallized areas while the small irregular circles are the amorphous regions. We see that the fibre may be regarded as an irregular flexible net built up of these two units and exhibiting at certain places larger holes which, of course, are in some way due to the origin of the material[5]. This structure is in general connected with the mechanical properties of the thread with its elasticity, plasticity, tenacity and its chemical reactiveness. The spaces and crevices between the crystallized areas absorb dye-stuffs, wetting agents and other reacting substances. They are of great importance to the behaviour of the fibre as a textile.



(*e*) We have reached a magnification of 1 to 5,000 and are now at the utmost limit of normal microscopic resolving power. The differentiation of picture *d* has disappeared and we observe a *fibrillar structure* in which the morphological units of the fibre are visible. They may be not so pronounced in artificial filaments and hence the above picture shows the fibrillar structure of a cotton fibre. The length, width and orientation of the fibrillæ are of great importance for all the finer textile properties such as elasticity, softness, lustre, creasability, etc.

(*f*) Switching in the next magnification, 1 to 500, we have finally reached the range of microscopical observation with normal light[6]. The picture shows a *viscose rayon thread* exhibiting a system of stripes parallel to its fibre axis. They are responsible for the soft lustre of the yarn, its pleasant appearance, and its easy dyeability. Pictures such as this are of great importance in technical routine tests carried out in rayon factories. The present one, for example, shows little specks indicating that some contamination of the material has taken place.

(*g*) This picture, with a magnification of 1 to 50, shows a bundle of a normal *viscose rayon thread*. Pictures of such kind are of importance to control the levelness of the yarn, its homogeneity in diameter, colour, dyeability and lustre.

(*h*) and (*i*) The last two pictures finally give us the well-known aspect of an artificial *silk yarn* with a magnification of 1 to 5 and without magnification at all. They need no explanation, being familiar to everyone.

The set of the above nine pictures may offer a certain insight into the structure of a very important substance starting from the trade product, namely, *rayon yarn*, and ending with the last detectable chemical unit, namely, the *glucose residue*. The location and understanding of every single structural principle is of importance, for each influences all the different technical qualities of the final product; the better and more accurate these nine pictures can be made, the higher will be the probability to make a rayon yarn of best quality.

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[1] See, Astbury, W. T., NATURE, **141**, 968 (1938). Clark, L. H., NATURE, **142**, 899 (1938). Bragg, W. H., NATURE, **142**, 910 (1938).

[2] Compare, Haworth, W. N., "The Constitution of Sugars" (London, 1929). In (*a*) the positions of the hydrogen atoms are omitted because they could not be located experimentally; shaded circles represent C-atoms, the open ones O-atoms. Dimensions of residue, 10·3 A. and 7·5 A.

[3] See, Polanyi, M., *Naturwiss*, **15**, 288 (1921). Sponsler, L. O., and Dore, H. W., *Coll. Symp. Mon.*, 174 (1926). Meyer, K. H., and Mark, H., *Ber.*, **61**, 593 (1928). Astbury, W. T., "Fundamentals of Fibre Structure" (Oxford, 1933), p. 77 *ff*. Gross, S. T., and Clark, G. L., *Krist.*, A, **99**, 357 (1938). Meyer, K. H., Misch, L., and Badenhuizen, N. P., *Helv. Chim. Acta*, **22**, 59 (1939). Crystallographic dimensions, $a = 8{\cdot}35$ A.; $b = 10{\cdot}3$ A., $c = 7{\cdot}9$ A.

[4] Astbury, W. T., *Trans. Farad. Soc.*, **28**, 232 (1932). Mark, H., *Rayon Record*, 498 (1932); *Trans. Farad. Soc.*, **29**, 6 (1933). Houwink, R., *Trans. Farad. Soc.*, **31**, 10, 28 (1935). Frey-Wyssling, A., *Prot.*, **25**, 262 (1936).

[5] Gerngross, O., Hermann, K., and Abitt, W., *Biochem. J.*, **228**, 499 (1930). Hermans, P. H., *Koll. J.*, **81**, 143, 300 (1937); **82**, 58; **83**, 71 (1938); **86**, 107 (1939). Kratky, O., *Koll. J.*, **80**, 139 (1937); **84**, 268 (1938). Kratky, O., and Mark, H., *J. Phys. Chem.*, B, **36**, 129 (1937).

[6] Farr, W. K., Eckerson, I., and Sisson, W. A., *Contrib. Boyce Thompson Inst.*, **6**, 189, 309, 315 (1934). Bailey, A. J., *Ind. Eng. Chem.*, **30**, 40 (1938).