Structural features of keratin suggested by its mechanical properties

As pointed out in a previous paper[1] a keratin fibre supercontracted in LiBr solution behaves as an elastomer at the end of both the first and final stages. Further, as shown by investigation of the mechanical properties of single wool fibre in 8 *M* LiBr at room temperature (20°), the force per unit extension at the end of the first stage of supercontraction is greater than the force per unit extension of the fully supercontracted fibre by a factor of 2.7_4. For the *same* fibres the ratio of contractions at the end of the final stage and the first stage was 2.8_2.

The simplest way to explain the concordance of these results is to assume that the process of supercontraction takes place in repeating sets of two end-to-end (series) components or zones in the fibre. The existence of series zones in wool fibre has been suggested by the results of a number of workers[7-11]. When rendered elastomeric, both of these components X and Y, to which we allot initial lengths x and y, are capable of the same percentage contraction, and have the same Young's modulus in this contracted state. We assume that contraction of X alone yields the first stage, and of Y alone the second stage of supercontraction.

The Young's modulus of wet wool is of the order of $2 \cdot 10^{10}$ dynes/cm², while that of fully supercontracted wool is only $7 \cdot 10^{7}$ dynes/cm². Hence at the end of the first stage of supercontraction, mechanical extension will be restricted to X, the elastomeric component. In the fully supercontracted fibre both X and Y would, under stress, have the same percentage extension. This model (see Fig. 1) leads therefore to an equation:

$$\frac{\text{Force per unit extension at end of first stage}}{\text{Force per unit extension at end of second stage}} = \frac{x+y}{x}$$

In addition,

$$\frac{\text{Supercontraction at end of second stage}}{\text{Supercontraction at end of first stage}} = \frac{(x+y)}{(x)\,c}\,c = \frac{x+y}{x}$$

Thus

$$\frac{x+y}{x} \approx 2.8$$

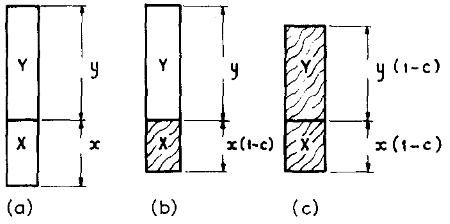

Fig. 1. A schematic representation of the series units proposed in keratin fibres. (a) The normal uncontracted fibre. (b) The fibre at the end of the first stage of supercontraction. X is elastomeric and its Young's modulus is very much less than the modulus of Y. The fibre has contracted by (cx). (c) The fully supercontracted fibre, contracted by $c\,(x+y)$. Both X and Y now are elastomeric.

Repeating units of two series zones, whose lengths are proportional to 1 and 1.8, might therefore exist in Corriedale wool fibres.

In addition, for wool fibres in water, creep, with loads corresponding to the yield region of the load-extension curve of a wet wool fibre, is asymptotic to 30 % extension[2,3] whereas for larger loads, corresponding to the post-yield region, creep curves are asymptotic to extensions of 75–85 %[4]. The ratio of these asymptotic extensions is approximately 80/30, *i.e.* 2.67, and could be explained by assuming that the first 30 % extension is primarily due to the X component, while extension from 30 to 80 % is primarily in the Y component. Finally, chemical or physical modifications of the mechanical properties of single fibres in the postyield region correlate with the ability of the fibres to supercontract in the final supercontraction stage[5,6].

We believe that the evidence outlined above favours the concept of series zones differing in accessibility and/or chemical composition in wool fibres. The two zones are most likely components of microfibrils, the matrix being converted immediately upon entry of LiBr solution into an elastomer. A full account of the experimental details will be given in a future paper.

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[1] A. R. HALY AND M. FEUGHELMAN, *Textile Research J.*, 27 (1957) 919.
[2] M. FEUGHELMAN, *J. Textile Inst.*, 45 (1954) T630.
[3] L. PETERS, *Proc. Intern. Wool Textile Research Conf. Aust.*, 1955, D-71–82.
[4] O. RIPA AND J. B. SPEAKMAN, *Textile Research J.*, 21 (1951) 215.
[5] M. FEUGHELMAN, A. R. HALY AND T. W. MITCHELL, *Textile Research J.*, 28 (1958) 655.
[6] M. FEUGHELMAN, R. A. HALY AND B. J. RIGBY, *Textile Research J.*, in the press.
[7] J. L. FARRENT, A. L. C. REES AND E. H. MERCER, *Nature*, 159 (1947) 535.
[8] G. H. JEFFREY, J. SIKORSKI AND H. J. WOODS, *Proc. Intern. Wool Textile Research Conf. Aust.*, 1955 F-130.
[9] I. MACARTHUR, *Nature*, 152 (1943) 38.
[10] R. D. B. FRASER AND T. P. MACRAE, *Nature*, 179 (1957) 732.
[11] W. G. CREWTHER AND L. M. DOWLING, *Textile Research J.*, submitted for publication.

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The net synthesis of cytochrome c in calf-heart mitochondria

Previous studies have shown that rat-liver mitochondria can effect the incorporation of labeled amino acids into cytochrome *c*[1]. We now report that calf-heart mitochondria can carry out this process over a much longer period of time, permitting the demonstration of a net increase in cytochrome *c* (Table I). This was observed (a) by adding labeled cytochrome *c* to each incubation flask at the end of the reaction (isotope dilution), and (b) by weighing the cytochrome *c* isolated by a modification[2] of available procedures[3]. The amount of cytochrome *c* formed increased linearly with time; the results of the gravimetric and isotope-dilution procedures are in excellent agreement. Both zero-time and 12-h samples of cytochrome *c* were assayed at 550 mμ by reduction by dithionite and oxidation by cytochrome oxidase[4], and gave results identical to those given by an authentic sample. The synthetic process requires energy and amino acids; omission of the complete amino acid mixture or of L-leucine not only stops synthesis but leads to degradation of endogenous cytochrome *c*. The possibility that the observed increase in cytochrome *c* is the result of combination of heme with preformed protein

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Abbreviations: FDNB, 1-fluoro-2,4-dinitrobenzene; DNP-, dinitrophenyl-.