ELEMENTS OF THE HELICAL STRUCTURE OF COLLAGEN

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IN a recent communication from this laboratory,[1] a structure has been proposed for collagen consisting of cylindrical "ropes", each rope containing three separate helical chains which are connected together by hydrogen bonds. On the basis of the structure, the meridional arc of spacing 2 86 Å was interpreted as the 113 reflection. The studies of Cowan *et al.*[2] with stretched collagen indicate that this the orientation is improved by stretching, both the intensity as well as the spread of the 2·86 arc diminish for the normal setting, while if the fibre is oriented at the correct angle for the meridional reflection, the 2·86 spot appears with greatly increased intensity. The 4·0 arc on the other hand, breaks up into two well-defined non-meridional reflections when the fibre is tilted to the appropriate angle.

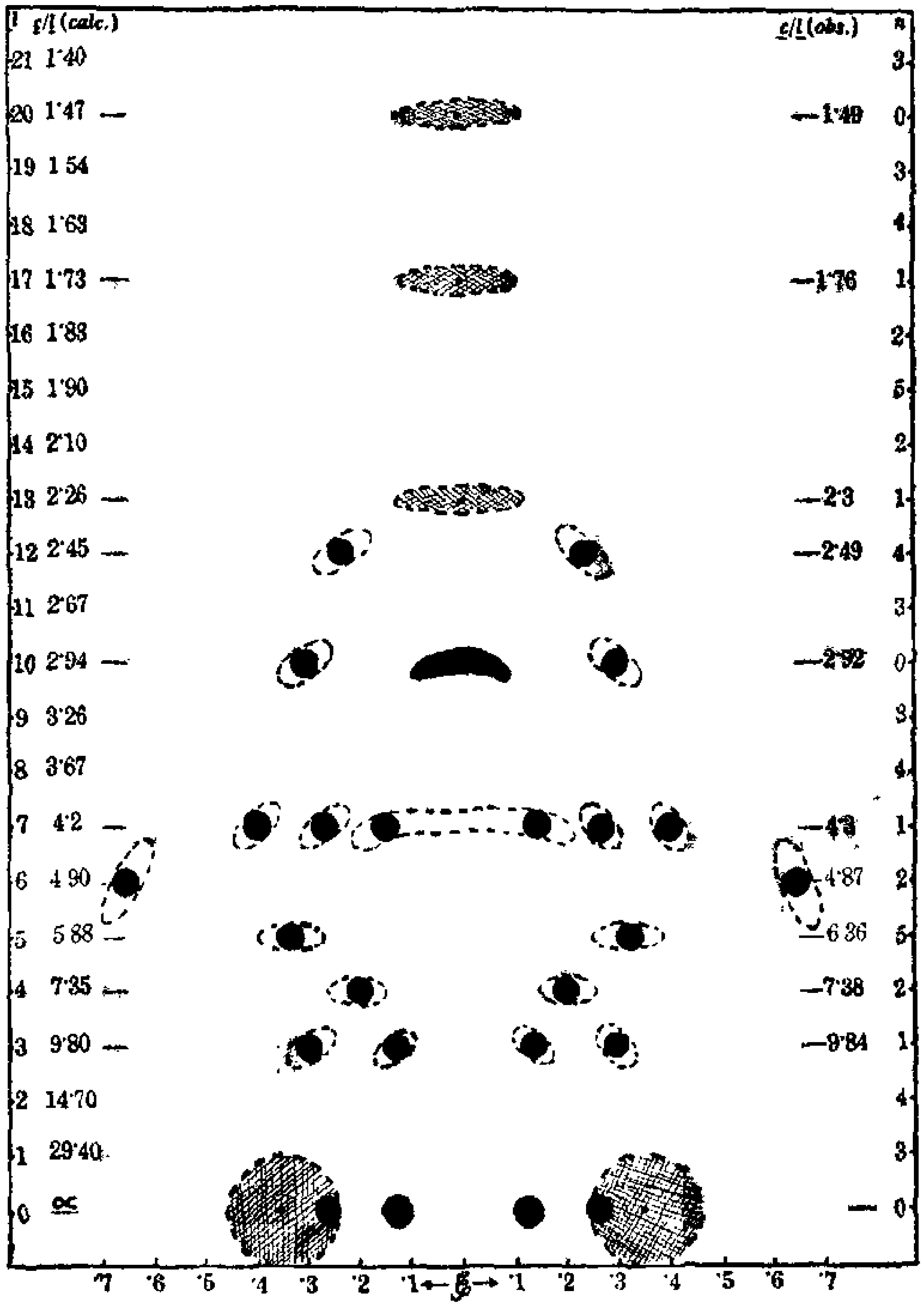

FIG. 1. Schematic diagram of X-ray diffraction pattern of stretched collagen.

reflection is truly meridional Recently the present authors have made similar studies under various conditions, such as different degrees of stretching and moisture content, and these confirm that the 2·86 Å arc is a true meridional reflection. The arc occurs in a photograph taken with the fibre axis at right angles to the X-ray beam only because a small fraction of the fibrils is highly disoriented. When

In view of the above, the earlier structure clearly requires revision. The photographs obtained show unmistakable evidence of the structure being helical, and they have been analysed with a view to determine the elements of the helix. Cohen and Bear[3] have proposed a helix making 2 turns in about 20 Å and having 7 groups of three residues each in two turns. Bear (private communication) has made some changes in this description, but the details are not known to the present authors. A careful analysis of the photographs of well oriented collagen show that the experimental data are not fully explained in terms of the above helix having $c = 20$ Å, but that they fit in well with a c-axis spacing of 28·6 Å. The data observed are schematically indicated in Fig. 1, where the layers are arranged according to their l-value and the ξ values of the reflections found in each layer are indicated by their x-co-ordinate. The data refer to a stretched specimen of air-dried kangaroo tail tendon, for which $c = 29 \cdot 4$ Å. The observed layer line spacings are shown on the right-hand side, and it will be noticed that they agree well with the calculated spacings, considering that the measurements are accurate only to about 5 per cent.

It is interesting that a reflection having a ξ value of approximately 0·20 is found in the fourth layer. The corresponding equatorial spacing is 7·7 Å and the absence of a reflection with this spacing in the zero-layer line has led to some authors[4] questioning the hexagonal unit cell proposed by Pauling and Corey.[5] The existence of this spot in the fourth layer supports the assumption of a hexagonal unit cell made by Ramachandran and Kartha.[1]

It is found that the intensities of the reflections found in the various layers could be explained if the helixes contain 10 residues in three turns, the spacing per residue being 2·94 Å. The intensities of the various spots which occur in the different layers are theoretically proportional to $J_n (2\pi R \xi)$,[6] where R is the radius of the helix and $J_n(z)$ is the Bessel function of z of order n, and n takes the values given by the equation

$$3n + 10m = l, \quad (m \text{ being integral}).$$

The smallest value of n which is operative for each layer is also given in Fig. 1. It will be seen that (*a*) for values of l from 3 to 10, practically all the expected layers occur, (*b*) all layers for which $n = 0$ or 1 are observed to occur, (*c*) the spots corresponding to $\xi = 0 \cdot 14$ occur only in layers having $n = 1$ or 0, and (*d*) when $n > 2$, no spots occur corresponding to $\xi < 0 \cdot 30$. These facts are in good agreement with what is to be expected from theory.

Further, the smallest ξ-value at which spots are observed in each layer can be used to determine the order of magnitude of the radius R of the spiral. This comes out to be of the order of 1 A. On examining the various helical structures proposed so far for collagen,[1,5,7–9] the only structure for which the radius of the helix is of this order is the one described from this laboratory.[1] The helix in that structure contains three residues per turn, while the above analysis of the X-ray data indicates that the helix should contain 3·33 residues per turn. It may be mentioned that the calculated density agrees much better with the experimental value with 3·33 residues rather than with 3 residues per turn. Thus, a small modification of the earlier structure would appear to be in good agreement with the X-ray and other data for collagen. Such a modification is not likely to affect the main features of the structure and the details are being worked out in this laboratory.

1. Ramachandran, G. N. and Kartha, G., *Nature*, 1954, **174**, 269.
2. Cowan, P. M., North, A. C. T. and Randall, J. T., *Nature and Structure of Collagen*, 1953, Butterworths, p. 241.
3. Cohen, C. and Bear, R. S., *J. Am. Chem. Soc.*, 1953, **75**, 2703.
4. Randall, J. T., Fraser, R. D. B. and North, A. C. T., *Proc. Roy. Soc.*, 1953, **141B**, 62.
5. Pauling, L. and Corey, R. B., *Proc. Nat. Acad. Sci. Wash.*, 1951, **37**, 272
6. Cochran, W., Crick, F. H. C. and Vand, V., *Acat. Cryst.*, 1952, **5**, 581.
7. Bear, R. S., *Advances in Protein Chemistry*, 1953, **7**, 69.
8. Crick, F. H. C., *J. Chem. Phys.*, 1954, **22**, 347.
9. Huggins, M. L., *J. Am. Chem. Soc.*, 1954, **76**, 4046

DR. K. R. RAMANATHAN

DR. K. R. RAMANATHAN, Director, Physical Research Laboratory, Ahmedabad, and Chairman, Atmospheric Research Committee, has been elected President of the International Union of Geodesy and Geophysics at the Tenth General Assembly Meeting held in Rome recently. His election to this high office is a gratifying recognition of his services to meteorology for nearly three decades, and is particularly well-timed in view of the global programme for the Third International Geophysical Year now under way. The wide range of his interests is amply reflected in the variety of topics dealt with by him in his scientific publications; but among them special mention may perhaps be made of the study of thermal structure and movements of the upper air, in which field his contributions are outstanding. Our heartiest felicitations to him on the honour conferred on him.