

LETTERS TO THE EDITORS

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Evidence for the Pauling-Corey α -Helix in Synthetic Polypeptides

We have calculated, in collaboration with Dr. V. Vand¹, the Fourier transform (or continuous structure factor) of an atom repeated at regular intervals on an infinite helix. The properties of the transform are such that it will usually be possible to predict the general character of X-ray scattering by any structure based on a regular succession of similar groups of atoms arranged in a helical manner. In particular, the type of X-ray diffraction picture given by the synthetic polypeptide poly- γ -methyl-L-glutamate, which has been prepared in a highly crystalline form by Dr. C. H. Bamford and his colleagues in the Research Laboratories, Courtaulds, Ltd., Maidenhead, is so readily explained on this basis as to leave little doubt that the Pauling-Corey α -helix², or some close approximation to it, exists in this polypeptide. Pauling and Corey² have already shown this correspondence in the equatorial plane; it is shown here that the correspondence extends over the whole of the diffraction pattern.

We quote here the value of the transform which applies when the axial distance between successive turns of the helix is P , the axial distance between the successive atoms lying on the helix is p , and the structure so formed is repeated exactly in an axial distance c . (For the latter condition to be possible, P/p must be expressible as the ratio of whole numbers.) In this case, the transform is restricted to planes in reciprocal space which are perpendicular to the axis of the helix, and occur at heights $\zeta = l/c$, where l is an integer. In crystallographic nomenclature, these are the layer lines corresponding to a unit cell of length c . On the l th such plane the transform has the value:

$$F(R, \psi, \frac{l}{c}) = f \sum_n J_n(2\pi Rr) \exp \left[in \left(\psi + \frac{\pi}{2} \right) \right]. \quad (1)$$

(R, ψ, ζ) are the cylindrical co-ordinates of a point in reciprocal space, f is the atomic scattering factor, and J_n is the Bessel function of order n ; r is the radius of the helix on which the set of atoms lies, the axes in real space being chosen so that one atom lies at $(r, 0, 0)$. For a given value of l , the sum in equation (1) is to be taken over all integer values of n which are solutions of the equation,

$$\frac{n}{P} + \frac{m}{p} = \frac{l}{c}, \quad (2)$$

m being any integer¹.

Thus only certain Bessel functions contribute to a particular layer line. This is illustrated in the accompanying table for the case of poly- γ -methyl-L-glutamate, for which Pauling and Corey² suggested $P = 5.4 \text{ \AA}$, $p = 1.5 \text{ \AA}$, and $c = 27 \text{ \AA}$. The first column lists the number, l , of the layer line, while the second gives the orders (n) of the Bessel functions which contribute to it (for simplicity only the lowest two values of n are given for each layer line).

Now there is, of course, more than one set of atoms in the polypeptide, but for all of them, P , p and c are the same, although r is different. The basis of

Value of l for the layer line	Lowest two values of n allowed by theory	Observed average strength of layer line (ref. 4)
0	0 \pm 18	strong
1	-7 \pm 11	
2	+4 -14	*weak
3	-2 \pm 15	very weak
4	+8 -10	
5	+1 -17	medium
6	-6 \pm 12	
7	+5 -13	
8	-3 \pm 16	weak
9	\pm 9	
10	+2 -16	weak
11	-5 \pm 13	
12	+6 -12	
13	-1 \pm 17	very weak
14	-8 \pm 10	
15	+3 -15	
16	-4 \pm 14	
17	+7 -11	
18	0 \pm 18	medium
19	-7 \pm 11	
20	+4 -14	
21	-3 \pm 15	
22	+8 -10	
23	+1 -17	trace
24	-6 \pm 12	
25	+5 -13	
26	-3 \pm 16	trace
27	\pm 9	
28	+2 -16	trace

Layers not described are absent.

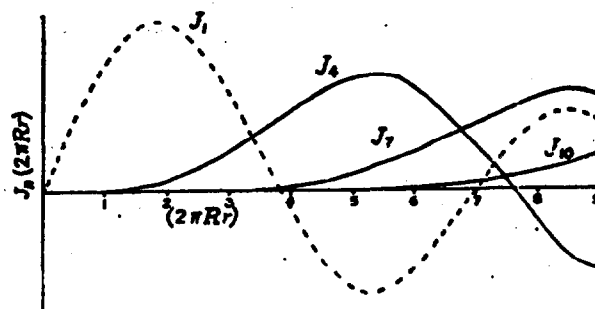
* (10/2), the reflexion having the smallest value of R , is absent.

our prediction is that a reflexion will be absent if the contribution of all sets of atoms to it is very small, and that on the average it will be strong if all sets of atoms make a large contribution.

It is a property of Bessel functions of higher order, illustrated in the graph, that they remain very small until a certain value of $2\pi Rr$ is reached, and that this point recedes from the origin as the order increases. Now, whatever the precise form of the chain, the value of r for any atom cannot be greater than about 8 \AA , because of the packing of the chains. This sets a limit to the value of $2\pi Rr$ within the part of the transform covered by the observed diffraction picture ($R < 0.3 \text{ \AA}^{-1}$ for $l \neq 0$). No set of atoms can make an appreciable contribution to the amplitude of a reflexion occurring on a layer line with which only high-order Bessel functions are associated, because $2\pi Rr$ comes within the very low part of the curve in the graph.

We should therefore predict that layer lines to which only high-order Bessel functions contribute would be weak or absent, and that those to which very low orders contribute would be strong.

These predictions are strikingly borne out by the experimental data⁴ summarized in the last column of the table. The significant Bessel functions involved in the first twenty-eight layer lines are shown in the second column, and, as will be seen, only layer lines associated with a function of order 4 or less



[The sixth of higher-order Bessel functions (with J_1 added dashed)

are represented. This limiting value of 4 is less than might have been expected, and this fact suggests that the contribution of the side-chains to any reflexion is small, probably due to their large thermal motion.

In addition, the theory predicts (as can also be shown by a simpler approach) that meridional reflexions can occur only on layer lines which involve Bessel functions of order zero; that is, at reciprocal spacings of multiples of $1/1.5 \text{ \AA}^{-1}$. This had previously been pointed out by Perutz² when reporting the strong meridional 1.5- \AA . reflexion.

We have therefore no doubt that the structure of poly- γ -methyl-L-glutamate is based on a helix of eighteen residues in five turns and 27 \AA ., or a helix which approximates to this very closely. As the structure proposed by Pauling and Corey³ satisfies these conditions and is also stereochemically very satisfactory, it seems to us highly probable that it is correct.

We should like to thank Dr. Bamford and his colleagues for allowing us to quote their experimental results in advance of publication, and Sir Lawrence Bragg and Dr. M. Perutz for the stimulus which their interest in this work has provided.

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¹ Cochran, W., Crick, F. H. C., and Vand, V. (to be published).

² Pauling, L., and Corey, R. B., *Proc. U.S. Nat. Acad. Sci.*, **37**, 241 (1951).

³ Perutz, M. F., *Nature*, **167**, 1053 (1951).

⁴ Bamford, C. H., Brown, L., Elliott, A., Hanby, W. E., and Trotter, I. F. (to be published).