this way was 12320 ± 170 (S.E.M.). Each measurement requires only 0.4 ml of solution; equilibrium is reached within 20 min.

Edmond, E., Farquhar, S., Dunstone, J. R. & Ogston, A. G. (1968) *Biochem. J.* **108**, 755–763
 Ogston, A. G. & Wells, J. D. (1970) *Biochem. J.* **119**, 67–73

Quaternary Structure of Helical Proteins with Globular Subunits

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The theory proposed (Milner-White, 1971, 1972) for studying the possible range of structures of oligomers assuming equivalence of the protomers also applies to helical proteins with globular protomers [e.g. actin filaments, bacterial pili or some rod-shaped virus coats; some enzymes (Olsen *et al.*, 1970) form enzymically active helical polymers]. For a summary of helix symmetries consult Klug *et al.* (1958).

Such proteins may be divided into two classes (heterologous-type and isologous-type). In one there is only heterologous binding between the protomers forming a helix. In this case the opposite ends of a single helix are different; such helices have polarity. In the other class each protomer has a minimum of two isologous site-pairs. The ends of such a helix are identical because of the dyad axes perpendicular to the helical axis; these helices lack polarity. (Sometimes two or more heterologous-type helices may lie antiparallel; in this case the protein will lack polarity).

In order to describe heterologous-type helices in terms of their binding-site structure it is necessary to define the angle ϕ (see Milner-White, 1972). ϕ is the angle between the planes of θ of two adjacent protomers measured in the plane perpendicular to the line joining their 'centres'. ϕ is defined as the clockwise rotation of the plane of θ of one protomer relative to that of the other protomer (as seen from the first protomer).

Parameters of the helix used are: $2\pi/\alpha$, the number of protomers per turn; r , the radius; h , the axial distance per protomer. ψ is another helix parameter. d is the distance between the centres of two adjacent protomers. These are related to ϕ and θ by the equations below (they apply for one heterologous site-pair; others may also be present). This approach will, we believe, be useful for the study of quaternary structure rather as the work of Ramachandran & Sasiekhara (1968) is useful for studying secondary structure.

$$h = d \cdot \sin \psi$$

$$d \cdot \cos \psi = 2r \cdot \sin \left(\frac{\alpha}{2} \right)$$

$$\sin \left(\frac{\alpha}{2} \right) = \cos \left(\frac{\theta}{2} \right) \cdot \sec \psi$$

$$\tan \psi = \tan \left(\frac{\theta}{2} \right) \cdot \sin \left(\frac{\phi}{2} \right)$$

Isologous-type helices with the same dimensions may be built if all the distances d are equal and if $\zeta_A = \zeta_B$. For such helices ϵ and $(\pi + 2\zeta)$ should be substituted for θ and ϕ in the above equations. With different geometry isologous binding may also generate more complex helicoid structures.

Klug, A., Crick, F. H. C., & Wyckoff, H. W. (1958) *Acta Crystallogr.* **11**, 199–213
 Milner-White, E. J. (1971) *Biochem. J.* **124**, 78P–79P
 Milner-White, E. J. (1972) *Biochem. J.* **128**, 107P
 Olsen, B. R., Svenneby, G., Kvamme, E., Tveit, B. & Eskeland, T. (1970) *J. Mol. Biol.* **52**, 239–245
 Ramachandran, G. N. & Sasiekhara, V. (1968) *Advan. Protein Chem.* **23**, 283–438

Differences in the Metabolism of Glucose between Normal and Dystrophic Human Muscle

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Fibre-bundle preparations of muscle biopsies were incubated with [^{14}C]glucose. HClO_4 extracts were made and chromatographed on paper, and the radioactivities of radioactive spots were counted. Metabolites were identified by co-chromatography with authentic substances; fructose was identified as its 1-methylphenylhydrazone (Neuberg & Mandl, 1946).

Fructose contained significantly more label in muscle extracts from patients affected with Duchenne-type dystrophy than in those from normal subjects. Radioactivity of fructose, expressed as a percentage of total incorporated ^{14}C , was $14.4 \pm 10.1\%$ (9) for normal subjects, compared with $43.2 \pm 14.7\%$ (8) for dystrophic subjects ($P < 0.001$ in the t test). The same parameter in other control groups had the following values: neurogenic muscle disease, $11.0 \pm 11.0\%$ (3); adult muscular dystrophy including myotonic dystrophy, $15.9 \pm 18.1\%$ (8); polymyositis, $25.0 \pm 21.8\%$ (6); normal foetal muscle (12–18 weeks' gestation), $21.2 \pm 17.8\%$ (6); female carriers of Duchenne-type dystrophy, $48.7 \pm 21.2\%$ (7). The value in Duchenne dystrophy is significantly raised compared with those in neurogenic muscle disease ($0.001 < P < 0.01$), foetal muscle ($0.02 < P < 0.05$) and adult muscular dystrophy ($0.001 < P < 0.01$). The value