and the search for an anti-sickling agent continues. Such an agent could be found by the trial-and-error screening of many compounds or by design based on the molecular details of fibre formation which are now emerging and which were summarised at the Dallas symposium.

The day began with B. C. Wishner (Johns Hopkins University, Baltimore) reporting on the structure of a crystalline form of haemoglobin S that may provide clues to the contacts between molecules in the fibres. In the crystals, molecules are arranged in paired strands, with adjacent strands within each pair staggered by half a molecule and rotated by half a turn. An intriguing feature of this crystal structure is that the β -6 position lies at an intermolecular contact between the strands within each pair, and several other sites implicated in the sickling process are also at or near contacts. If the axis of the strands in the crystals corresponds to the fibre axis *in vivo*, the orientation of the molecules in the crystals also satisfies critical optical dichroism data. Thus the juxtaposition of molecules in the crystals could bear a close resemblance to the arrangements in the fibres (with minor adjustments for converting the planar alignment of the crystals to the helical alignment of the fibres).

The possibility of a close relationship between the crystals and the fibres was strengthened by the presentation of S. J. Edelstein (Cornell University, Ithaca) on the structure of the fibres determined by electron microscopy, in collaboration with R. Josephs (Weizmann Institute of Science, Rehovot). The fibres were prepared by lysis of sickled cells directly with solutions of negative stain, revealing eight-stranded fibres with adjacent strands staggered by half a molecule as the predominant form in all 10 individuals with sickle cell disease examined. The structure of the fibres was deduced from optical diffraction and Fourier transform analysis of the electron micrographs and is consistent with an assembly of four pairs of strands in the general arrangement found in the crystals studied by Wishner *et al.* Uncertainties remain, including whether adjacent pairs of strands would be parallel or antiparallel and why the eight-stranded, staggered-strand structure was not detected in earlier studies by Finch *et al.* (*Proc. natn. Acad. Sci. U.S.A.*, **70**, 718; 1973).

On the basis of solubility studies of artificial hybrid haemoglobin constructed of β -S and various α -chain mutant forms, R. Benesch (Columbia University, New York) reported five new α -chain positions apparently involved in sickling. The two positions

Light in dielectrics

from a Correspondent

FOR the past sixty years there has been disagreement about the ratio of momentum to energy carried by electromagnetic waves in dielectrics. Abraham said $1/nc$; Minkowski said n/c , where c is the speed of light *in vacuo* and n the refractive index, so that c/n is the speed of light in the medium. The question relates to the correct choice and interpretation of the energy-momentum tensor. Subsequent contributors though relatively few have been exceptionally distinguished. This is doubly surprising. First, electromagnetic theory leaves no genuine scope for controversy; second, when the fog began to clear around 1973, the question was found to turn on a clear and detailed description, on the molecular level, of what precisely is measured in any given experiment. In other words the apparent simplicity of the problem as originally formulated proved deceptive.

Continuing the early and especially elegant discussion by Ginzburg (*Sov. Phys. (Uspekhi)* **16**, 434; 1973) and Gordon (*Phys. Rev.*, **A8**, 14; 1973), further steps towards clarifying the issue have now been published by Sir Rudolf Peierls (*Proc. R. Soc. Lond.*, **A347**, 475; 1976). Central to the issue is the distinction between the purely electromagnetic momentum (which by itself would lead to Abraham's result), and the mechanical momentum induced in the molecules of the medium. In an infinite amorphous

(fluid) medium a broad enough light pulse leaves no mechanical disturbance in its wake; but on reflection from an interface it deposits mechanical stresses and strains just upstream of the interface, and these must be considered carefully in accounting for any observations. Professor Peierls has found that to leading order in (n^2-1) , the operative result is the mean of Abraham's and Minkowski's. To higher order in (n^2-1) , there may be need to reflect further on this result, which, (as Peierls himself discusses), is *prima facie* in conflict with some arguments in the classic text by Landau and Lifshitz (*Electrodynamics of continuous media*, Pergamon Press, 1960). For narrow beams (with width to length ratio less than the ratio between the speed of sound and light), there are other effects, some of experimental importance considered already by Gordon (*op. cit.*), and another fascinating one found by Professor Peierls, reminiscent of Cerenkov radiation, of sound generation by the light pulse.

One thing that will surely be needed soon is a systematic textbook-level discussion explaining *ab initio* what results are applicable in what circumstances. For instance, a very recent low-frequency experiment on a solid dielectric (Walker *et al.*, *Can. J. Phys.*, **53**, 2577; 1975) is accounted for by Abraham's result alone, while in many quantum-mechanical applications Minkowski's result, alone, can be used; the "momentum" implied by the latter is then analogous to the so-called "crystal-momentum" of phonons.

with the strongest influence on sickling, $\alpha 47$ and $\alpha 54$, were among the α -chain locations predicted to lie at contacts from the model building based on the electron microscopic results noted above. Thus several lines of investigation are converging on the structural details of the fibres, and a definitive description may soon emerge. While such information should help in the design of anti-sickling agents, there are also likely to be many physical-chemical subtleties in fibre assembly yet to be appreciated. One such subtlety emerged from the presentation of A. N. Schechter (National Institutes of Health, Bethesda) concerning a synthetic peptide corresponding to the first 13 residues of the β -S chain. The peptide binds to an antibody elicited in response to haemoglobin S, but does not itself influence fibre formation. Conformational differences between normal haemoglobin and S were also reported by C. Ho (University of Pittsburgh) on the basis of nuclear magnetic resonance studies. Therefore

some aspects of conformation may be critical, along with other possible factors related to intermediate structures and rate limiting steps in fibre assembly.

The 11 other presentations dealt principally with aspects of fibre assembly using various techniques to monitor assembly, including an elegant application of water proton relaxation rates reported by M. R. Waterman (University of Texas, Dallas). Various stages in the assembly process were described on the basis of viscosity by H. F. Bunn (Harvard Medical School, Boston) and ultracentrifugation by R. W. Briehl (Albert Einstein College of Medicine, New York). W. A. Eaton (National Institutes of Health, Bethesda) presented a particularly cogent analysis of the delay time, t_d , for fibre formation, in relation to the "supersaturation ratio", S , raised to a power, n , equivalent to the order of the reaction:

$$1/t_d = \gamma S^n$$

where S is defined as the total concentration of haemoglobin S divided by the