are not the expression of the combinations of two alleles as was supposed[2], but involve three alleles. The six phenotypes resulting from the three alleles are all distinguishable, but only, at present, after the haptoglobins have been purified, dissociated into their component polypeptides by reduction in the presence of a denaturant, and separated in acidic starch-gels containing 8 *M* urea. This example of intra-species protein differences which are normally hidden suggests the need for caution in presuming identity of proteins until their complete amino-acid sequence has been established. A similar situation exists in the mammalian insulins of different species which are indistinguishable by physical methods[3].

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Linkage between Glucose-6-Phosphate Dehydrogenase Deficiency and Colour-Blindness

A LINKAGE investigation has been carried out in American Negroes to confirm that deficiency in glucose-6-phosphate dehydrogenase is sex linked rather than sex limited[1], and, if sex linked, to determine the recombination fraction (χ) between the loci for deficiency in glucose-6-phosphate dehydrogenase and colour-blindness; further, through the use of linkage, to see if the difference between the expression of deficiency in glucose-6-phosphate dehydrogenase in Negroes and Caucasians[2] is explicable on the basis of different genetic loci in the different ethnic groups.

Among 3,649 American Negro school-boys, 134 were found to be colour-blind. One hundred and six of these, and their brothers, totalling 238, were screened for glucose-6-phosphate dehydrogenase activity[3]. Both the traits were found in ten families. Of these

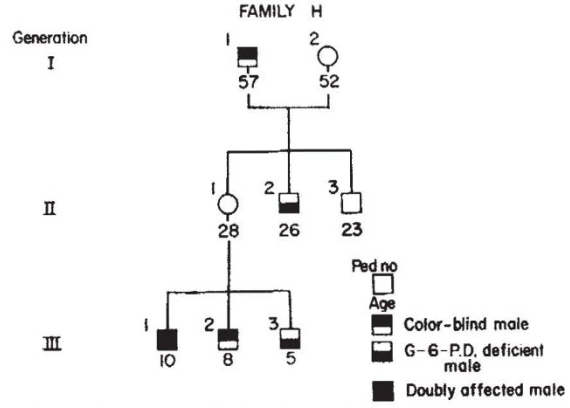

Fig. 1. Genes responsible for the two traits are in the repulsion phase in II, 1 and hence III. 1 represents the cross-over

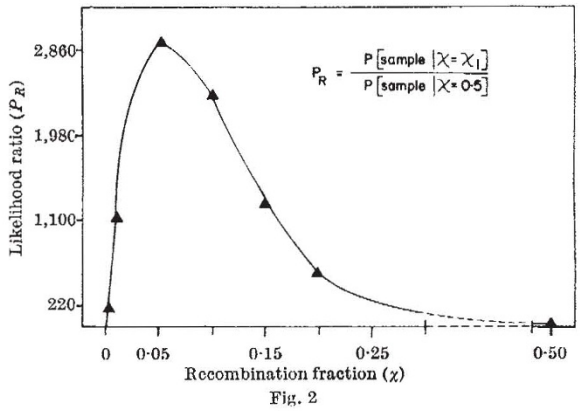

Fig. 2

we were able to investigate 8. The members of these were tested for type and degree of colour-blindness and for quantitative glucose-6-phosphate dehydrogenase activity[4].

There were 6 families with the deutan type of colour-blindness. In 3 of these the 2 traits were in the coupling phase, and in 3 they were in the repulsion phase in the mother of the probands. The one definite cross-over (Fig. 1) occurred in one of the latter families.

There were 2 families with protan type of colour-blindness. The traits were in coupling in one, and in repulsion in the other family.

The data were analysed by the IBM 7090 computer, which is programmed (Renwick, J., and Schulze, J., unpublished results) to deal with pedigrees for linkage by the method of lod scores[5]. The six pedigrees with deutan type of colour-blindness and deficiency in glucose-6-phosphate dehydrogenase, with 30 scorable offspring, gave a maximum likelihood estimate for the recombination fraction (χ) of 0·05 (Fig. 2) with 90 per cent confidence limits of 0·009 and 0·18. A small ascertainment correction is included in this result.

In the two families with protan type of colour-blindness and deficiency in glucose-6-phosphate dehydrogenase, with only about 8 scorable offspring, the probability was, with a 90 per cent confidence limit, that the recombination fraction (χ) was less than 0·2.

Linkage between the enzyme-deficiency locus and the sex-linked colour-blind locus establishes that glucose-6-phosphate dehydrogenase deficiency is also sex linked and not sex limited.

Comparison between the results of this study and similar studies by Adam[6] and Siniscalco[7] in Caucasians provides no evidence for more than one sex-linked glucose-6-phosphate dehydrogenase locus.

The results are insufficient to support a one or two locus hypothesis for the two types of colour-blindness.

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