from NATURE, *Vol.* 158, *page* 558, *October* 19, 1946.)

Gene Recombination in *Escherichia coli*

ANALYSIS of mixed cultures of nutritional mutants has revealed the presence of new types which strongly suggest the occurrence of a sexual process in the bacterium, *Escherichia coli*.

The mutants consist of strains which differ from their parent wild type, strain *K*-12, in lacking the ability to synthesize growth-factors. As a result of these deficiencies they will only grow in media supplemented with their specific nutritional requirements. In these mutants single nutritional requirements are established at single mutational steps under the influence of *X*-ray or ultra-violet[1,2]. By successive treatments, strains with several requirements have been obtained.

In the recombination studies here reported, two triple mutants have been used: *Y*-10, requiring threonine, leucine and thiamin, and *Y*-24, requiring biotin, phenylalanine and cystine. These strains were grown in mixed culture in 'Bacto' yeast-beef broth. When fully grown, the cells were washed with sterile water and inoculated heavily into synthetic agar medium, to which various supplements had been added to allow the growth of colonies of various nutritional types. This procedure readily allows the detection of very small numbers of cell types different from the parental forms.

The only new types found in 'pure' cultures of the individual mutants were occasional forms which had reverted for a single factor, giving strains which required only two of the original three substances. In mixed cultures, however, a variety of types has been found. These include wild-type strains with no growth-factor deficiencies and single mutant types requiring only thiamin or phenylalanine. In addition, double requirement types have been obtained, including strains deficient in the syntheses of biotin and leucine, biotin and threonine, and biotin and thiamin respectively. The wild-type strains have been studied most intensively, and several independent lines of evidence have indicated their stability and homogeneity.

In other experiments, using the triple mutants mentioned, except that one was resistant to the coli phage *T1* (obtained by the procedure of Luria and Delbrück[3]), nutritionally wild-type strains were found both in sensitive and in resistant categories. Similarly, recombinations between biochemical requirements and phage resistance have frequently been found.

These types can most reasonably be interpreted as instances of the assortment of genes in new combinations. In order that various genes may have the opportunity to recombine, a cell fusion would be required. The only apparent alternative to this interpretation would be the occurrence in the medium of transforming factors capable of inducing the mutation of genes, bilaterally, both to and from the wild condition. Attempts at the induction of transformations in single cultures by the use of sterile filtrates have been unsuccessful.

The fusion presumably occurs only rarely, since in the cultures investigated only one cell in a million can be classified as a recombination type. The hypothetical zygote has not been detected cytologically.

These experiments imply the occurrence of a sexual process in the bacterium *Escherichia coli*; they will be reported in more detail elsewhere.

This work was supported in part by a grant from the Jane Coffin Childs Memorial Fund for Medical Research.

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Sept. 17.

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