B. Genetic recombination: the sexual process in Escherichia coli
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1. Sexual incompatibility

In previous work on the sexual recombination mechanism in Escherichia coli it had been concluded that all strains of the K-12 line of this species were equally competent to function in the sexual process. This was based particularly on the absence of any obvious segregation of mating preferences among the progeny of crosses. It has been necessary to revise this concept, however, in the light of the discovery of certain strains which we will call "F-" in contrast to the wild type F+. F- strains are characterized by their total sterility in combinations with each other, that is, all crosses of F- by F- are completely non-productive, whereas F- by F+ and F+ by F+, corresponding to all previous work, are productive of genetic recombinants. The first F- strains to be discovered were causual isolations for which we could assign no basis for the occurrence of the F- change. More recently, however, it has been discovered (Dr. P. D. Skaar) that F- strains could be artificially produced by passing F+ strains through semi-solid agar and selecting for optimal motility. The mechanism of this effect has not been elucidated. The most remarkable feature of the F+ system is the restoration of F- strains to the F+ state by simple mixed culture of F- with F+ strains. While the transfer of the F+ state occurs with very high efficiency it has not yet been possible to separate any virus-like agent from F+ cultures which would have this restoring effect. The way in which the F+ state controls the sexual process in Escherichia coli remains obscure. Other lines of Escherichia coli have been found in this laboratory in which the F state appears to play no direct role. Other workers have, however, speculated that the transfer of the F+ trait is mediated by a virus-like agent which has also the property of transferring, under exceptional circumstances, part or all of the genetic material of the bacterium. We have not been able to

reconcile this speculation with the totality of the data that have been accumulated here, but for the present are not able to offer any substantial alternatives. Until the mechanism of the transfer of the F+ state is clarified the entire question is bound to be obscure. All that can be certainly stated at the present time is that at least one of the parents must be in the F+ state for a cross to succeed.

The F+/- polarity of the parents also plays an important role in modifying the segregational behavior of a given cross. In general the recombinants tend to show a considerable excess of the markers originally carried by the F- parent, and this finding has been part of the basis for the speculation previously mentioned, with the suggestion that the "F+ agent" may usually transfer only a fragment of the genetic material of the parent cell. Our studies on the behavior of unreduced diploids obtained from crosses of varying polarity have ruled out this interpretation and we have been led instead to the rather more complex notion that there is a partial elimination of the genetic material that had been originally been contributed in full by the F+ parent. This elimination must take place subsequent to zygote formation and crossing over to account for the character of the diploids that we have analyzed (T. C. Nelson).

Considerable effort continues to be directed to the demonstration of the sexual process on a morphological as well as a genetic basis. As the attached figure 1 shows it is possible to make cytological preparations of mixed cultures of the K-12 line in which there are paired elements highly suggestive of a conjugal process. Considerable attention is being paid, however, to the numerous artifacts in appearances of both cellular and nuclear structures which may be the consequence of current cytological methods as applied to bacteria, and we are not yet in a position to assert with any confidence that the figure here demonstrated is free from such artifacts. These cytological studies with fixed and stained preparations are being carried out coordinately with studies with

on living cells. Linked pairs of cells are not infrequently seen in living preparations but their possible significance with respect to the sexual process remains to be assessed.

The discovery in 1951 and 1952 of some 50 additional strains of Escherichia coli which displayed genetic recombination encouraged the hope of an immunogenetic analysis in this species. Preliminary studies soon indicated that the different fertile lines that had been isolated were of a very wide variety of serological types and that there was no obvious correlation between any serological or cultural characters within the species Escherichia coli and the ability to undergo the sexual process. In the present studies some 5% of the strains tested within this species have shown genetic recombination. At the present time we do not know what factors, if any, limit the possible occurrence of sexuality in the remaining strains. Unfortunately, ~~as the work of many authors [illegible] has all too abundantly shown, as well~~, Escherichia coli does not lend itself very well to serological study. The component antigens show marked interference with one another in the usual serological tests and even the best antisera that can usually be obtained have relatively low titers. In addition, the over-all antigenic structure of the E. coli group is so complex that it was not feasible ~~at the present time~~ to attempt to develop a range of serological reagents such as would be necessary for an adequate immunogenetic analysis. However, it has been possible to demonstrate with a number of distinct lines that the three groups of antigenic factors that have been described by other workers--the so-called O, K and H--are separable by genetic recombination, and that new combinations of the various antigenic factors can be synthesized by this same process. In general however the Salmonella group has proved to be far superior for such purposes, the advantages of the greater serological simplicity, or our ability to rely on the much more extensive work that has already been done by other workers, outweighing the possible disadvantages of the more restricted genetic recombinational system in that genus. However, [illegible] to the human blood groups.