

Zinder N D & Lederberg J. Genetic exchange in Salmonella.  
*J. Bacteriology* 64:679-99, 1952.

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**A phenomenon by which genes in bacteria are exchanged and recombined has been discovered. The temperate bacteriophage, PLT-22, during growth has its genome replaced by bacterial genes. Each particle carries about one percent of the bacterial genome. These genes are carried to a new host cell in phage-like particles and can replace their homologous genes. The frequency is about  $10^{-5}$ /gene/particle. The phenomenon is called transduction. [The SCI<sup>®</sup> indicates that this paper has been cited in over 190 publications since 1961.]**

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"When I arrived in July 1948 in Lederberg's lab at the University of Wisconsin, it was one of those golden times in science. A new field, bacterial genetics, had just been born. It had no substantial past, no literature, just discoveries lying around waiting to be picked up.

"I had not been there three months when we developed the penicillin enrichment technique (negative selection) for bacterial auxotrophic mutants. This was important for me as my thesis work was to be an attempt to extend Lederberg's<sup>1</sup> finding of conjugation in *E. coli* K12. Many pairs of different mutants would be needed for the search. Auxotrophic mutants of *S. typhimurium* strains were to be mixed *inter se* and pairwise seeking prototrophic recombinants.

"For six months or so I diligently built up the set of mutants, doing an occasional cross and some coli genetics to relieve the monotony. Most of the attempts to cross the mutants failed. However, one particular mutant strain gave small numbers of prototrophs when crossed with several strains and a large number with one. Surprisingly, other markers, nine in all, did not segregate. There

appeared to be no linkage as existed in coli conjugation. The phenomenon was also asymmetric. Individual markers in one of the strains could be selected but not those of the other. Although resembling DNA-mediated transformation, the phenomenon was not DNase-sensitive.

"We turned to a procedure originally devised by Bernard Davis<sup>2</sup>—a U-tube with a bacterial sterile filter between the arms—to determine whether cell contact was necessary. It wasn't. When I told Lederberg, he sat down heavily and muttered that I should go work with Hotchkiss, who was working on transformation. Ultimately, I did. Quickly we determined that mixed cultures gave sterile filtrates containing large amounts of an activity that affected selective markers in many strains. The filtrates also contained a temperate phage. Because of how little we knew about phage or temperate phage at the time (1950-1951), this finding wasn't all that helpful. In a not quite straight path of research and analysis, we finally showed that the activity was in phage-like particles. Bacterial genes (soon to become DNA) were substituted for phage genes and transferred to the phage's next host. We called the phenomenon transduction—to lead across.

"Citation of this paper is not surprising as it documents the discovery and use of one of the three fundamental mechanisms of genetic exchange in bacteria—transduction; the others are conjugation and transformation. General transduction<sup>3</sup> provides the means for fine genetic analysis of genome structure. The discovery shortly thereafter of special transduction<sup>4</sup> complemented and added to the power of these procedures. The paper also describes phage P22 (then called PLT-22) which became, with lambda (special transduction), the two paradigms for the study of temperate bacteriophages.

"Today, we also recognize transduction in the oncogenic activities of some retroviruses and the effects of the constructs on recombinant DNA. "

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2. Davis B D. Nonfiltrability of the agents of recombination in *Escherichia coli*.  
*J. Bacteriology* 60:507-8. 1950.

3. Ikeda H & Tomizawa J. Transducing fragments in generalized transduction by phage PI.  
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4. Morse M, Lederberg E & Lederberg J. Transduction in *E. coli* K-12. *Genetics* 41:121-33.