F' and F Mediated Transduction in *Escherichia coli* K12

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Three mating types have been known in *E. coli* K12; Hfr, F⁺ and F⁻ (Lederberg *et al.* 1952). Recently Adelberg and Burns (1959) discovered another mating type F', possessing a determinant called *sfa* (sex factor attachment). This type was found in the process of reisolation of Hfr. It is characterized by infective transfer of the Hfr character and also by the same oriented transfer of the host chromosome as is shown by the original Hfr strain.

This report deals with a study on F' strains (Hirota 1959) derived from different Hfr strains and a new kind of transduction (F-duction) which is associated with matings involving F' cells.

Similar studies on F' have been reported independently by Jacob and his associates (Jacob *et al.* 1959, 1960).

Terminology F' (*F prime*): A group of sex-determinants of *Escherichia coli* which carry a small fragment of bacterial chromosome (autosome) in a linked state with a sex-factor, F. They are generally characterized experimentally by their contagiousness to F⁻ cells, autonomous reproduction within the host cell, oriented transfer of the host chromosome and accessibility to acridine treatment. A male which carries F' is designated as F'⁺. Different F's are designated by putting an arabic numeral under the letter F (e.g. F₂, F₃ etc.). For convenience, we use the arabic numeral of the Hfr from which the F' was derived (e.g. F₃, for an F' isolated from Hfr₃).

F-mediated transduction (or F-duction or Sex-duction): Linked transfer of a small fragment of bacterial chromosome with F in the course of mating. The transformed cell receives the fragment with F in a transductional event.

Materials and Methods

The strains used in this experiment are summarized in Table 1. Most of the Hfr cultures have the capacity of infecting their Hfr-character to F⁻ strains when mixed with the latter. This usually occurs with very low frequency, an exception is Hfr₁, which does not yield F' variants. This is presumably accounted for by a difference in stability of the original *non-infectious* Hfr to *infectious* Hfr, that is, F'⁺.

Isolation of F': The method used for isolation of these F's which spontaneously arise in Hfr cultures is as follows:

An overnight culture of F⁻ is mixed with an excess Hfr (routinely, 10⁸F⁻: 10⁸Hfr

Varieties of F': Five distinctly different F' strains have been isolated from Hfr strains or found in the stab-collection: F_H from Hfr_H (Hayes's Hfr) (Hayes 1953), F₃ from Hfr₃ (Richter 1959), F₄ from Hfr₄ (Richter 1959), in F₃ noninfective Hfr₃ was not found in the stab culture and F₁₃ from Hfr₁₃*. The history, their properties and the scheme are summarized in Table 1 and Fig. 1 respectively.

Experiments

Infectivity (contagious infection): F₂⁺, F₄⁺, F₈⁺ and F₁₃⁺ can infect their male behavior to F⁻ with very high frequency just as standard F⁺ does (Lederberg *et al.* 1952). 50 to 80 per cent of the F⁻ cells are converted into F⁺ after overnight incubation of mixed culture at 37°C. The minimal number of F₄⁺ cells required for infection of F₄ within one hour is less than 10³ cells per ml. In other words, these F' strains show high contagiousness. F₃ which is isolated from Hfr₃ by the method, is very unstable and easily reverted into F⁺.

Reisolation of F₃⁺ from the culture gives stable F₃⁺, but the infectivity of the F₃ and F from F₃⁺ to F⁻ is very low as in Hfr₃.

Determination of maleness: Each F' determines a characteristic pattern of chromosome transfer of the host cell. The marker transferred with the highest frequency (about 10⁻²) corresponds to the leading marker in the oriented transfer of the chromosome in an Hfr mating. The frequency agrees with the order of gene arrangement obtained from recombination analysis and from interrupted mating experiments by several workers (Richter 1959; Cavalli and Jinks 1956; Wollman *et al.* 1956) (Fig. 1).

The pattern of the fertility and order of transfer of chromosomal markers are determined by F' itself. For example, F_H⁺ shows the same pattern of fertility and oriented transfer of chromosome as Hfr_H (Wollman *et al.* 1956); it is highly fertile for transfer of T, Ara₂, L, Lac₁, Gal₂, . . ., and less fertile for Arg₁, Mal₁, Xyl₂ and Mtl. F₄ controls the chromosome transfers in the same order as Hfr₄ (Richter 1959); namely, Arg₁, Mal₁, Xyl₂ and Mtl are transferred with high frequencies and Ara₂, Lac₁ and Gal₂ are transferred with low frequency.

However, F₁₃⁺ shows some unusual features. The original Hfr₁₃ transfers Gal with high frequency and Lac with low frequency. However, F₁₃ shows two states of fertility; (State II) highly fertility for Pur₁, V₆ and Lac and low fertility for Gal; (State I) high fertility for Gal, Try, Mtl and M and low fertility for Lac like Hfr₁₃.

F₈⁺ shows high fertility for Gal₂, Lac₁, Prol, . . . in this order, but low fertility for Try, Arg₁, Mal₁, Xyl₂ and M.

Cure of maleness: All F' agents can be removed with acridine treatment similar to the wild type F (Hirota and Iijima 1957; Hirota 1960). Accessibilities of F₈ and F to the treatment are almost the same (Table 2): An overnight treatment of F₈⁺ or F₄⁺ with 30 micrograms per ml of acridine orange in nutrient broth (pH 7.6, inoculum size: 10⁸ cells per ml) gives a high ratio of conversions.

* Originally isolated by Dr. E. M. Lederberg.

Table 2. Comparison of accessibility of F and F₈ to acridine treatment

	Treated with AO				Untreated control				Treated with AO				Untreated control			
Strains treated	W4519+W6				W4519+W6				W4527+W4520				W4527+W4520			
	F ₈ ⁺	F ⁻	F ⁺	F ⁻	F ₈ ⁺	F ⁻	F ⁺	F ⁻	F ⁺	F ⁻	F ₈ ⁺	F ⁻	F ⁺	F ⁻	F ₈ ⁺	F ⁻
No. of colonies obtained after treatment	6	50	6	53	55	0	55	0	0	59	0	95	32	0	32	0
Per cents of F ⁻ obtained	89.3%		89.9%		0%		0%		100%		100%		0%		0%	

AO: acridine orange, 30 micrograms per ml.

Genotype of the strains used: W6: M-F⁺, W4519: M-Mal₁-S^rF₈, W4520: M-F₈⁺, W4527: M-Mal₁-S^rF⁺. Overnight cultures of F₈⁺ and F⁺ are mixed in ratio 1:1 and are inoculated into nutrient broth (inoculum size: ca. 10⁴ cells/ml., pH of the medium 7.60) with or without 30 micrograms of acridine orange. These treated cultures are then seeded on EMBmaltose agar plate to score them (both strains). The Mal⁺ and Mal⁻ colonies are tested on their compatibilities.

Reinfection with F of the females obtained by disinfecting F₈⁺ or F₄⁺ yields standard F⁺. However, a female obtained from the stable F₈⁺ by the treatment of acridine gives F₈ type male after infection of F, and gives two states of fertility as Richter described (Richter 1959).

Mutation of F': Mutation of F'⁺ (F₄⁺ and F₈⁺) into F⁺ and also disinfection of F' are observed after heavy doses of UV-light irradiation (so as to give 1 in 10⁶ survivors). The rate of conversion from F'⁺ to F⁺ is about 10⁻³ per survivor and the rate of disinfection of F' is about 10⁻⁴ to 10⁻⁵ per UV-survivor.

Infection by F': The F' agent from F₄ and F₈ can infect F⁺ after mixed culture after overnight growth at 37°C, from 3 to 10 per cent of F⁺ (W4327) cells yield mixed colonies of F⁺ and F'⁺ cells. Presumably the mixed colony arises from a cell which carried double F, F and F', and segregation occurs.

The F^r strain (Lederberg and Lederberg 1956) shows resistance to infection by F' as well as F.

F mediated transduction of various markers: F' can control a sexual process by which the host cell transfers a long chromosomal segment in the same way as standard Hfr. Some F' variants also behave as a vector transferring a small fragment of chromosome (F mediated transduction or F-duction).

Exponentially growing, cultures of W4520 (S^rM-F₈) and W4573 (F-Lac₈₅Gal₂MtlXyl₂Mal₁S^r) were mixed and incubated at 37°C in Penassy broth and plated on EMBGal medium at varying times. Each plate was replica plated onto EMBMtl and EMBXyl (Fig. 2). The total number of Gal⁺ colonies increased 1.2 to 2.0 times faster than the host cell and donor cell after mixed culture. The rate is decreased at stationary growth phase of bacteria.

About 60 to 80 per cents of F-Gal⁻ colonies are converted into Gal⁺F₈⁺ after overnight culture as described above.

W3747 (F₁₃⁺M-V₈^r) can transduce a Lac-segment with very high frequency and

the segment can spread over the population more rapidly than the host cell as the same way as F_8 .

This high rate of multiplication of F' is similar to the behaviour of F (Leder-

Fig. 2. Exponentially growing, 4×10^7 cells per ml of W4520 ($F_8M^-V_6^+$) and 2×10^8 cells per ml of W4573 ($F^-Gal_2Lac_{85}Ara_2Xyl_2Mal_1Mtl$ Sr) are mixed and the 10^{-6} ml is seeded on EMBgalactose medium at each time and scored the total number of Gal^+ and Gal^- colonies.

After incubation of the plates, they are replica plated on EMB-Xyl and EMBMtl agar, and counted the ratio of Xyl^+Mtl^+ and Xyl^-Mtl^- colonies.

Using these method, it is possible to differentiate between $Gal^+Xyl^+Mtl^+$ (W4520), $Gal^-Xyl^-Mtl^-$ (W4573) and $Gal^+Xyl^-Mtl^-$ (F -ductants). Increase of each markers can be plotted.

The starting points of these curves were plotted at the same point for comparison of rate of multiplication of each marker.

berg 1958).

However, the transducible markers of these F' are very limited compared with sexual recombination processes. For example, F_8 can transduce the Gal-cluster of genes but not Try, Indol, Anth and Lp which are markers close to Gal, and the transducible markers of F_{13} are restricted to the $Pur_1V_6Mb^+P^*Lac$ -segment while Gal and Pr which are markers close to Pur and Lac segment (Fig. 1, Table 3) are not F-duced by F_{13} .

Most of the transduced cells form stable heterozygotes for F-duced markers by F-duction (heterozygous diploid or heterozygous polyploid) and behave as donors which can re-transduce the transduced segment to the other F^- as the original F'^+ does.

The nature of heterogenote obtained by F-duction: The heterogenote (Morse *et al.* 1956) formed by F-duction can be characterized by four traits as follows:

1) The heterogenote transduces the exogenote genes with ca. 100 times greater frequency than the endogenote (Morse *et al.* 1956) (Table 4).

2) The heterogenote colonies are somewhat unstable and most of the colonies contain ca. 10^{-2} to 10^{-3} of segregants.

Analysis of the segregational pattern of the heterogenote shows that the majority of the segregants now carry the endogenotic gene in the chromosome, a few per cent carry the exogenotic gene, and recombined types appear as rare events. F^- , F^+ , Hfr and F'^+ types, including hemizygotes and homozygotes of F'^+ , can be obtained from the heterogenote.

Table 3. Size of transduced segment by F-duction of F_{13}

Markers of transduced colonies by F ₁₃ segment												
Markers selected			Unselected markers tested							No. of colonies	Per cent	
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1. W3747(F ₁₃ M-V ₆ r) [—] × W4541 (F-Lac ₈₅ -Gal ₂ -Xyl ₂ -Mtl-P-Mal ₁ -V ₆ rSr)												
S	Lac	Xyl ₂	Mtl	Mal ₁	Gal ₂	V ₆	P	M	Sex			
r	+	-	-	-	-	r	-	+	male	306	97.2%	
r	+	-	-	-	+	r	-	+	male	9	2.86%	
<hr/>												
2. W4870 (F ₁₃ Gal ₂ Xyl ₂ Mtl P V ₆ r) [—] × W2594 (F-Lac ₁ V ₁ rM Sr)												
S	Lac	Xyl ₂	Mtl	Mal ₁	Gal ₂	V ₆	P	M	V ₁	Sex		
r	+	+	+	+	+	r	+	-	r	male	19	4.83%
r	+	+	+	+	+	s	+	-	r	male	5	1.27%
r	+	+	+	+	+	r/s	+	-	r	male	367	93.4%
r	+	+	+	+	-	r/s	+	-	r	male	2	0.51%

r/s: Variegation for virus resistance.

1 ml of overnight culture of F_{13}^+ , F^- , and 1 ml of fresh broth are mixed and incubated for overnight at 37°C. Then they are purified on EMBlactose agar plate containing streptomycin.

$Lac^+ Sr^-$ colonies converted by F-duction at the rate of ca. 70% of total Sr^- colonies grown on the selective medium are tested on their unselected markers.

*) U_7 , U_{18} , U_{19} and U_{24} (Microbial Genetics: Cambridge press, p239: 1960) kindly given from Dr. A. Garen, and P^- of W4871.

†) Y. Sugino, unpublished.

Table 4. Comparison on the fertility of endogenote and exogenote of the heterogenote

Male strains	Lac ₈₁ / ex Lac ₂ F ₁₃ *		Lac ⁺ / ex Lac ⁺ F ₁₃	
Female strains	× Lac ₂ -F-S ^r (exogenotic)	× Lac ₈₁ -F-S ^r (endogenotic)	× Lac ₂ -F-S ^r (exogenotic)	× Lac ₈₁ -F-S ^r (endogenotic)
Fertility (No. of Lac ⁺ transductants per donor)	10 ⁻⁴ ~10 ⁻⁵	10 ⁻¹ ~10 ⁻²	10 ⁻¹ ~10 ⁻²	10 ⁻¹ ~10 ⁻²

Excess F⁻ strain was mixed with male (ratio: 10:1) at 37°C for 2 hr in Penassy broth, and seeded the culture onto MLacSm agar after appropriate dilution.

* The exogenote (Lac₂-F₁₃) might be hemigenote judged by reversion test.

F-duction of Lac₈₁ F₁₃ segment to Lac⁺S^rF⁻ gives state I type, Hfr type male, Lac₈₁F₁₃S^r suggesting integration of F₁₃ segment into endogenote.

The above two phenomena are quite similar to the heterogenotes produced by lambda transduction (Morse *et al.* 1956).

3) The episome can be removed by acridine treatment, causing a loss of male capacity. The rate of segregation of endogenotic types is remarkably increased after the treatment (Table 5). This contrasts with the behavior of F⁺, in which only F is removed.

In other words, linked elimination of the exogenotic F', F and the linked fragment, does occur after treatment of syngenote (Morse *et al.* 1956) with acridine dyes.

4) Complementing pairs of Gal mutant using F₈ and Lac mutants using F₁₃ have yielded Gal or Lac⁺ heterogenotes, as lambda system (Morse *et al.* 1956). This makes complementation analysis using F' possible.

Timing experiment of F-duction and structure of F₁₃: Time analysis of the F-duction process using a blender for separating mating pairs was done using F₁₃ (Wollman *et al.* 1956). The time for transduction of whole segment of F₁₃ including Pur, V₆, Lac and Sex was about 5 minutes at 37°C: F-duction of Pur starts between 5 to 10 minutes after mixing, and transfer of Lac begins between about 10 to 15 minutes.

The transduced cells which received Pur but not Lac were female. The time of entry of maleness is the same as Lac marker under this experimental condition, suggesting the site of attachment of F in F₁₃ is near the distal end of the segment, as it is in the Hfr (Wollman *et al.* 1956) (Table 6).

Transduction of Gal by F₈ starts within 4-5 minutes after mixing. The Gal fragment of F₈ can also be separated by blending at early stage of F₈-duction, but the frequency of separation is very low.

Experiments to show separate transfer of F and of Lac from F₁₃⁺ to F⁻ were negative. However, a considerable fraction of Lac⁻ segregants from Lactose variegated colonies from exconjugants which are formed within 3 minutes after mixing of the parents shows the F⁺ trait indicating that F can be easily released from F₁₃ segment after its transfer from F⁺ to F⁻.

It is plausible to assume that in this mating process a mechanism analogous to zygotic induction of prophage is operating (Wollman *et al.* 1956).

Table 5. Treatment of syngenote (Lac₁/ ex Lac⁺; Gal_{1,2}/ ex Gal⁺) with acridine orangeA. Effect of AO to Lac F₁₃ segment

Tube no.	Treated with acridine orange			Untreated control		
	Lac ⁺ male female	Lac ⁻ male female	Lac ₀	Lac ⁺ male female	Lac ⁻ male female	Lac ₀
I.	291 (30.7%)	650 (68.2%)	11 (1.1%)	1248 (78.5%)	333 (21.0%)	8 (0.50%)
No. of colonies tested for sex- compatibility	149	138		146	116	
	149 0 (100%) (0%)	22 116 (15.9%) (84.1%)		146 0 (100%) (0%)	116 0 (100%) (0%)	
II.	43 (20.5%)	116 (79.0%)	1 (0.5%)	756 (89.0%)	88 (10.3%)	6 (0.7%)

B. Effect of AO to Gal F₈ segment.

Tube No.	Treated with acridine orange		Untreated control	
	Gal ⁺ male female	Gal ⁻ male female	Gal ⁺ male female	Gal ⁻ male female
I.	521 (54.9%)	428 (45.1%)	2257 (96.1%)	90 (3.9%)
No. of colonies tested for sex- compatibility	119	122	106	60
	118 1 (99.2%) (0.8%)	7 115 (5.7%) (94.3%)	106 0 (100%) (0%)	58 2 (96.7%) (3.3%)
II.	445 (60.8%)	287 (39.2%)		

Experimental conditions of acridine treatment: Inoculum size, ca. 10 cells; Nutrient broth^a pH. 7.6; concentration of AO, 30 micrograms per ml; 37°C, overnight treated. The treated and untreated cultures are seeded onto EMB agar to score the ratio of segregation, and the colonies are tested on their sex-compatibility.

Control on the state of F' by the controlling element, Rfd₃: Infection of female-3 (W3644: F⁻ Rfd₃TLTh⁻ Mal₅-Sr⁻) (Richter 1959) with F₈ gives F₈ type male, and it gives two states of fertility just as Hfr₃ does: a high fertile state and a low fertile state with respect to the transfer of the methionine marker. The former state is relatively less fertile than the latter with respect to the transfer of the Gal-segment. In other words, there is a complementary relationship between transfer of M and Gal markers. These two states are interconvertible.

Table 6. Time analysis of F-duction by F₁₃

Time of interruption (min.)		Number of transductants								
		0'	5'	10'	15'	20'	25'	30'	35'	40'
Marker selected	Pur ⁺ (EM glucose)	0	0	3	30	141	599	1039	1226	1542
	Pur Lac ⁺ (EM lactose)	0	0	0	7	129	194	1055	917	1182
Number of Pur ⁺ transductants tested on V ₆ Lac and Sex.		0	0	3	28	55	50	54	64	58
	Pur ¹	—	—	3 (100%)	26 (93%)	24 (44%)	23 (46%)	11 (20%)	7 (11%)	1 (1.7%)
	Pur ¹ V ₆ ¹	—	—	0	0	2 (3.6%)	3 (6%)	2 (3.7%)	0	0
	Pur ¹ V ₆ ¹ Lac ¹	—	—	0	1 (3.5%)	2 (3.6%)	0	0	0	0
	Pur ¹ V ₆ ¹ Lac ¹ Sex ¹	—	—	0	1 (3.5%)	27 (49%)	24 (48%)	41 (76%)	57 (89%)	57 (98%)

W3747 was mixed with excess W4861 with ratio 10⁷ vs. 10⁸ in Penassay broth at 37°C with gentle shaking. Sample was taken at each time, chilled to stop the transduction, blended with mixer and seeded on selective media (EM glucose and EM lactose agar).

Pur⁺ colonies are picked from EM glucose agar plates and tested on their unselected markers; V₆, Lac and sex-compatibility.

Discussion

Hfr strains have always been derived from F⁺ strains as a consequence of the fixation of F at a certain locus on the chromosome; they then lose the property of transmitting F by infection and the male factor becomes inaccessible to acridine dyes (Hirota 1960). Hfr strains are more or less readily revertible to F⁺, suggesting that release of F from the Hfr chromosome (Lederberg and Lederberg 1956; Lederberg 1959) can occur.

We can most plausibly postulate that F' carries a small fragment of host chromosome and that it can make a facultative association with a certain site of host chromosome; it becomes free from the chromosome at certain time of the life cycle (plasmid state) and can also make synapsis (chromogenic state) and be integrated into the host chromosome during synapsis.

The relatively unstable Hfr strains can mutate to F'⁺, presumably splitting off their F together with a small fragment of chromosome which was linked to the F in the original Hfr cell. The F'⁺ acquires infectivity and susceptibility to acridine dyes in this way: Presumably the F' is yielded by fragmentation of distal end of Hfr chromosome, or by quite alike mechanism as translocation of host chromosome to F, or by recombination between F and the host chromosome.

Infection of F' into F⁻ produces the plasmid state: In this state the F agent, together with the associated chromosome fragment, can multiply much faster than host

chromosome, and has high contagiousness, and can be cured with acridine treatment (Hirota 1960; Lederberg 1959).

When the F' carries a chromosomal marker such as Lac or Gal, the infection of the F' is recognized as F-duction and the marker is spread through the population with the F property by cell contact, and it is eliminated by acridine treatment. The F' also determines the transfer of host chromosome, that is, the mating process, there is therefore a dual system of gene transfer.

If the F' has no markers on the linked segment, transfer of the chromosome segment can be recognized only by the characteristic high fertility of the F' cell, which is therefore shown as the infective transfer of the Hfr character.

Exchange of the chromosomal segment of F' with the host chromosome also involves a kind of synapsis and crossing over between F' and the host chromosome, as with the lambda system (Morse *et al.* 1956).

Segregation of $Lac_{s_2} F_{13}$ homogenotes from $Lac_{s_2}/ex+$ heterogenote has been observed, and presumably occurs via a four-stranded or multistranded stage as in lambda-heterogenotes (Morse *et al.* 1956).

The determination of maleness may be interpreted on the same basis. F' may make synapsis with the segment of host chromosome which is allelic to the segment covered by the F' and it then determines a point of breakage of host chromosome, (Wollman *et al.* 1956) at a neighboring site by some unknown mechanism of integration of the F' .

In consequence of the accurate synapsis of the chromosomal segment of F' to the host chromosome, the host cell can behave like the original Hfr from which the F' was derived.

The attached markers of F_2 or F_4 are not known yet, but they may carry a determinant which was linked with F in the original Hfr strains, Hfr₂ and Hfr₄ respectively.

Mutation of F' to F after UV-light irradiation appears to correspond to the loss of a chromosome fragment which was linked with F' . The linked transduction of maleness with chromosomal markers and in the linked elimination by acridine treatment, and the timing experiments of F-duction using F_{13} , support the hypothesis that the compound structure of F' and F attaches near the distal end of the transducible fragment.

However, release of F from F_{13} (i. e. from the compound particle consisting of F and the Lac segment) after transduction into F cells suggests that there might be a mechanism analogous to zygotic induction of prophage (Wollman *et al.* 1956). In the present case F is released from F' and appears in the progeny as F. This scheme requires the further assumption of a controlling element in F'^{+} and in Hfr cells which determines the point of reattachment of the released F to a certain site of the F' or the Hfr chromosome, similar to Rfd₃ and sfa (Adelberg and Burns 1959; Richter 1959).

F_3^{+} seems especially interesting. The F_3 (isolated from Hfr₃) can be transferred

by infection and is present in an unstable state.

Reisolated stable F_3^+ from the unstable clone shows poor infectivity of the F_3 character, similar to the original Hfr_3 , suggesting that there is a weak association of Rfd_3 with F (Richter 1959). Treatment of the reisolated F_3^+ with acridine dye gives a female-3 type of F^- (Richter 1959) reflecting the strong association of Rfd_3 and the host chromosome. The unstable F_3^+ gives plain F^- after treatment with acridine.

The two states of F_3Rfd_3 male may correspond to the plasmid state and the chromogenic state respectively (Richter 1959).

Many kinds of F' can be expected, each carrying different sizes or different kinds of chromosomal segments. Wild type F and F' may correspond, respectively, to a sex-chromosome and a sex-chromosome which carries a fragment of autosome of bacteria.

Summary

Several F' agents which carry various sizes and different kinds of chromosomal segment have been isolated. These are infective and can determine certain male type of behavior by controlling the oriented transfer of the host chromosome. The F' agent can also pick up genes of the host cell and can exchange these genes with host cell chromosome. This agent has high contagiousness and can multiply faster than the host cell. Cells carrying F' can be cured with acridine treatment. Some F' agents carry chromosomal markers which are transduced when F' infects another cell.

The transductants form stable heterogenotes. Complementing pairs of mutant markers have given the wild type on segregation. Thus segregation, due to crossing over between the chromosome and the chromosomal fragment of F', occurs within the heterogenote. F' transduces the exogenotic gene with higher frequency than the endogenotic gene. The episomic state of F' can be controlled with Rfd_3 .

The process of F-duction is quite like as mating process of Hfr .

A hypothesis on the structure of F' and the mechanism of determination of maleness by F' is discussed.

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