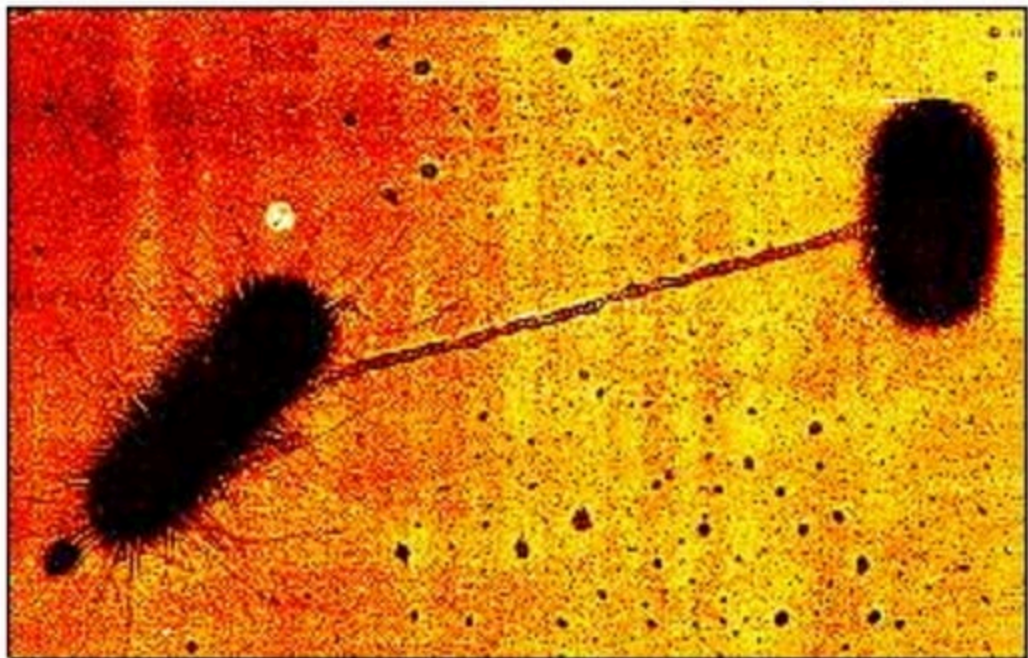


7

The Genetics of Bacteria and Their Viruses



Plasmids

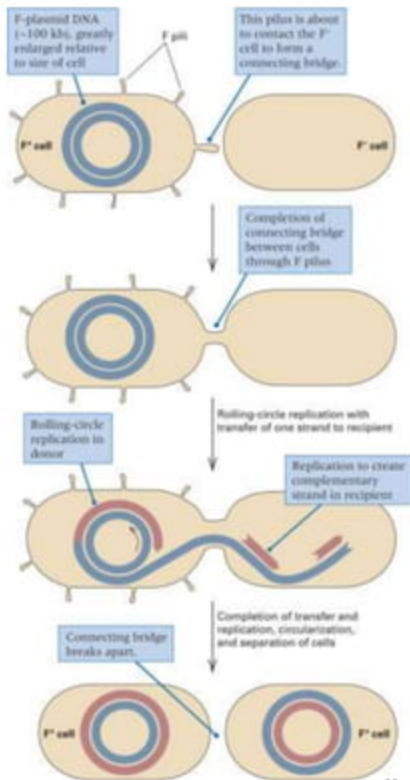
- Many DNA sequences in bacteria are mobile and can be transferred between individuals and among species.
- Plasmids are circular DNA molecules that replicate independently of the bacterial chromosome
- Plasmids often carry antibiotic resistance genes
- Plasmids are used in genetic engineering as gene transfer vectors

F factor and Conjugation

- F (fertility) factor is a conjugative plasmid transferred from cell to cell by conjugation
- F factor is an episome = genetic element that can insert into chromosome or replicate as circular plasmid
- The F plasmid is a low-copy-number plasmid ~100 kb in length, and is present in 1–2 copies per cell
- It replicates once per cell cycle and segregates to both daughter cells in cell division

F factor and Conjugation

- Conjugation is a process in which DNA is transferred from bacterial donor, F⁺ cell to a recipient, F⁻ cell by direct contact.
- The transfer is mediated by a tube-like structure called a pilus, formed between the cells, through which the plasmid DNA passes.
- Once in contact, conjugation, DNA transfer is unidirectional. The lagging strand template peels away... and is transferred to the recipient.
- The leading strand template is replicated in the donor while the lagging strand template is replicated in the recipient... so that both cells wind up with the plasmid.

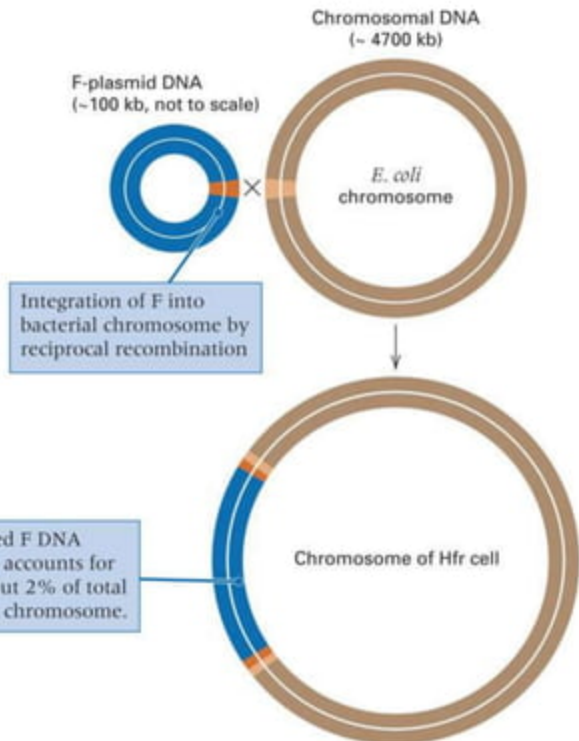


Conjugation

- In bacterial mating, conjugation, DNA transfer is unidirectional

Hfr

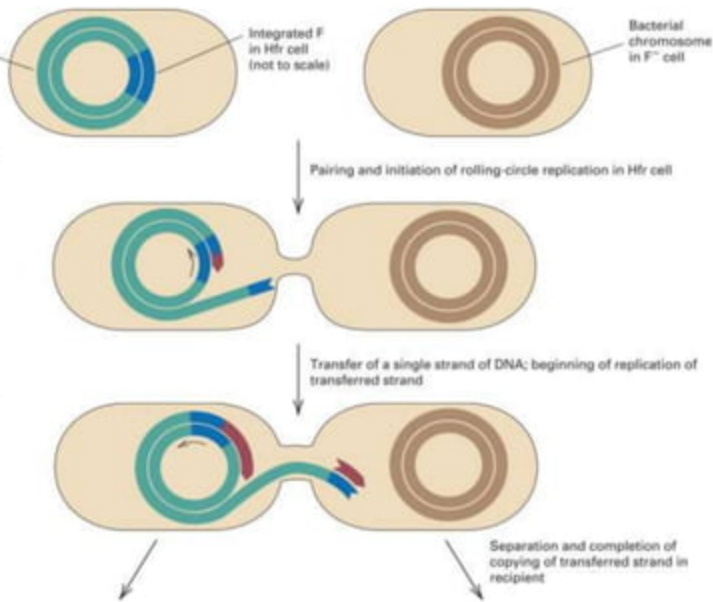
- F factor can integrate into chromosome via genetic exchange between IS elements present in F and homologous copy located anywhere in bacterial chromosome
- Cells with the F plasmid integrated into the bacterial chromosome are known as Hfr cells
- When an Hfr cell undergoes conjugation, the process of transfer of the F factor is initiated in the same manner as in an F⁺ cell
- However, because the F factor is part of the bacterial chromosome, transfer from an Hfr cell also includes DNA from the chromosome
- Hfr = high frequency of recombination



- Transfer begins within an integrated F factor and proceeds in one direction
- A part of F is the first DNA transferred, chromosomal genes are transferred next, and the remaining part of F is the last
- The conjugating cells usually break apart long before the entire bacterial chromosome is transferred, and the final segment of F is almost never transferred

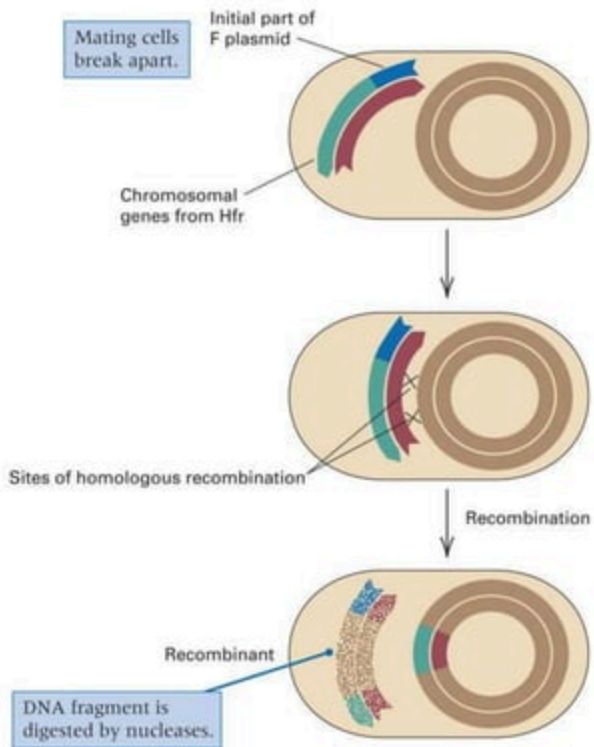
The recipient cell remains F⁻

Hfr and Conjugation





Rolling-circle replication stops

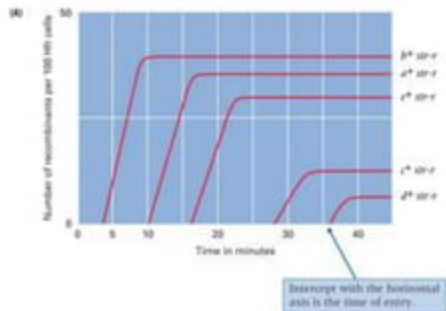


Chromosome Mapping

- It takes 100 minutes for an entire bacterial chromosome to be transferred and about 2 minutes for the transfer of F
- The difference reflects the relative sizes of F and the chromosome (100 kb versus 4600 kb)
- Regions in the transferred DNA may incorporate into the recipient chromosome and replace homologous regions
- This results in recombinant F⁻ cells containing one or more genes from the Hfr donor cell

Chromosome Mapping

- Genes in the bacterial chromosome can be mapped by Hfr x F⁻ mating



Genetic maps from Hfr strains

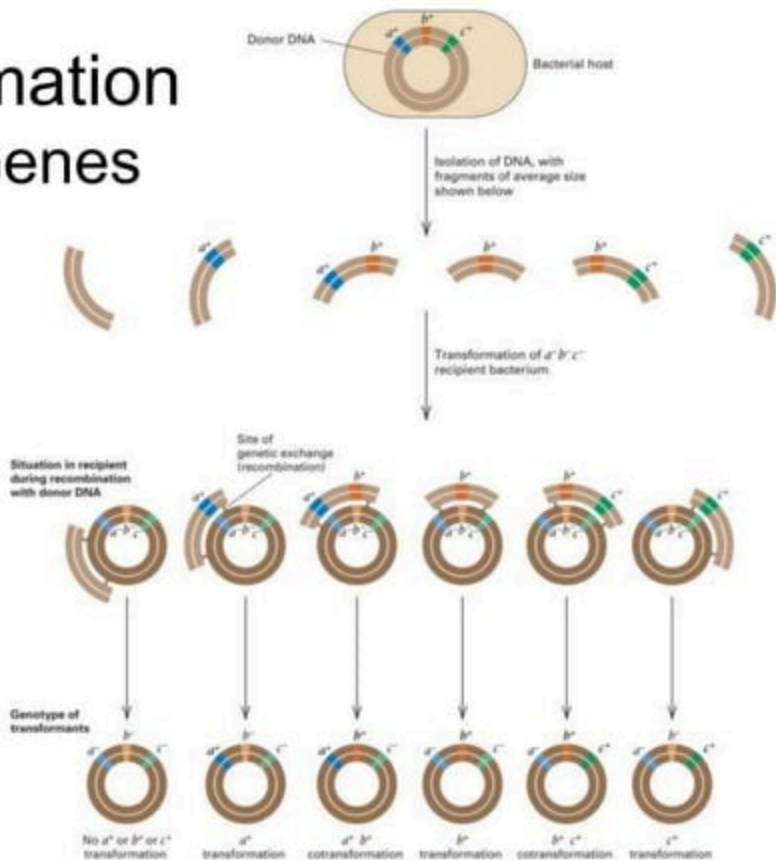
Fig. 7.13a-e

Bacterial Transformation

- The process of genetic alteration by pure DNA is transformation
- Recipient cells acquire genes from DNA outside the cell
- DNA is taken up by cell and often recombines with genes on bacterial chromosome
- Bacterial transformation showed that DNA is the genetic material
- Transformation may alter phenotype of recipient cells

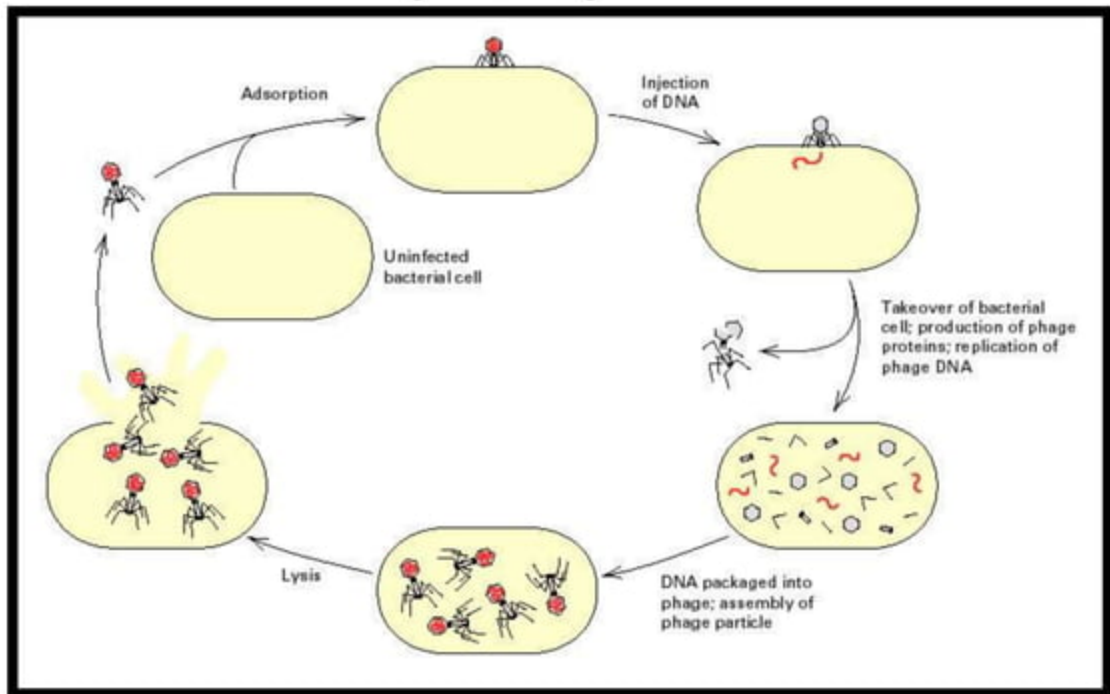
Cotransformation of Linked Genes

- Genes located close together are often transferred as a unit to recipient cell = cotransformation
- Genes that are far apart are less likely to be transferred together
- Cotransformation is used to map gene order



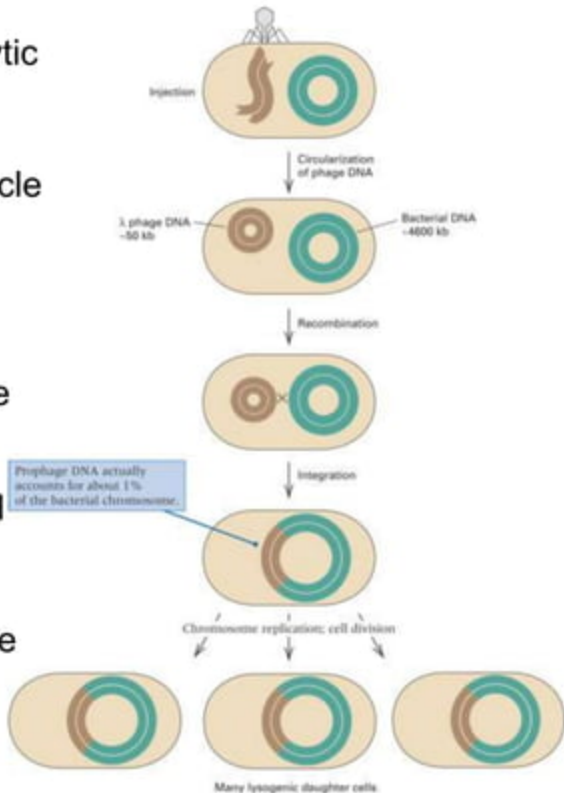
No $a^+ b^+ c^+$ or $a^+ b^+ c^+$ cotransformation occurs because the distance between a and c is too great.

Lytic Cycle



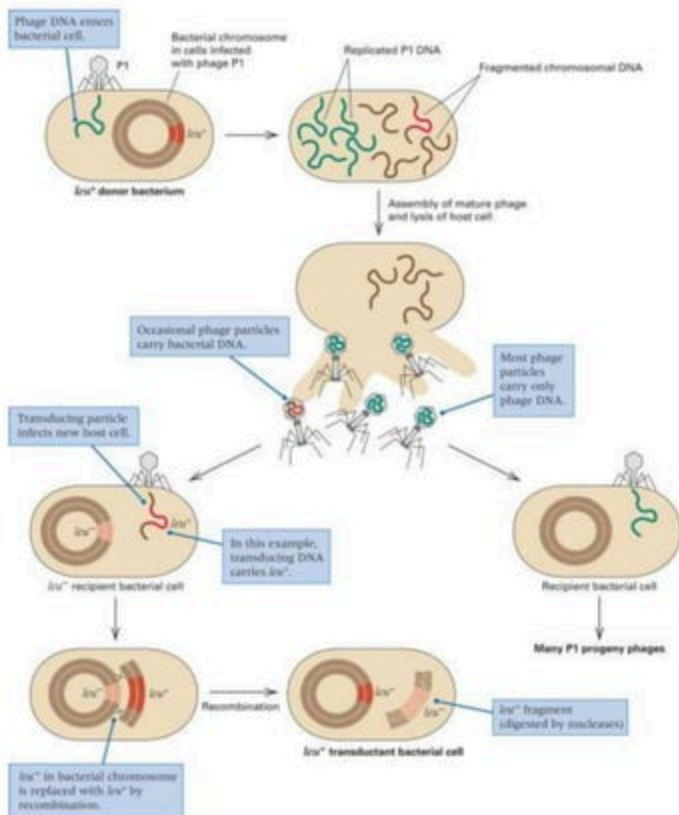
Lysogenic Cycle

- All phage species can undergo a lytic cycle
- Phages capable of only the lytic cycle are called virulent
- The alternative to the lytic cycle is called the lysogenic cycle: no progeny particles are produced, the infected bacterium survives, and a phage DNA is transmitted to each bacterial progeny cell when the cell divides
- Those phages that are also capable of the lysogenic cycle are called temperate

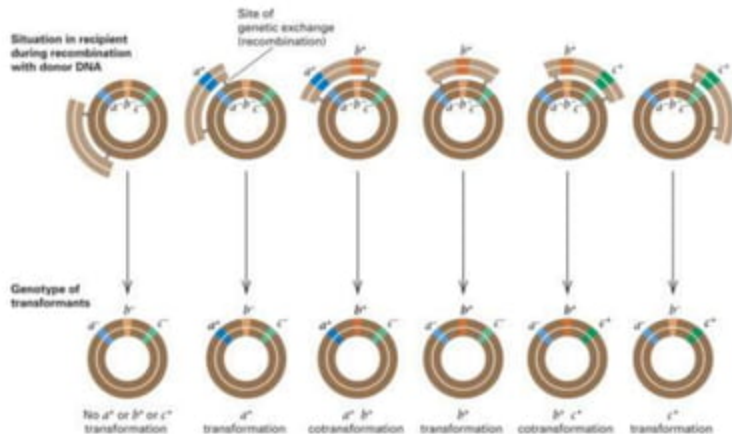


General Transduction

- A bacterial virus, or bacteriophage, transfers the DNA from one bacterial cell to another
- During a LYTIC infection, a transducing phage, such as P1 infecting *E. coli*, *accidentally* packages a piece of the bacterial chromosome into a virus particle instead of its own viral DNA.
- The phage carrying the bacterial DNA then delivers it to the recipient cell when it tried to infect again.
- The injected bacterial DNA may then be inserted into recipient chromosome by homologous recombination



Transduction



No *a*⁺ *b*⁺ *c*⁺ or *a*⁺ *b*⁺ *c*⁺ cotransformation occurs because the distance between *a* and *c* is too great.

- A typical P1 virus can hold about 80 kb of bacterial DNA in its viral particle... or about 50 genes
- The probability of simultaneous transduction of two genes (cotransduction), depends on how close to each other the two genes are. The closer they are, the greater the frequency of cotransduction
- Cotransduction provides a valuable tool for genetic linkage studies of short regions of the bacterial genome

Transposable Elements

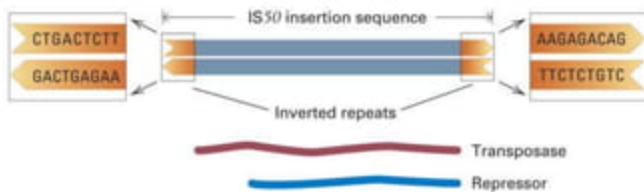
- Transposable elements are DNA sequences that can jump from one position to another or from one DNA molecule to another
- Bacteria contain a wide variety of transposable elements (as do all other organisms studied to date)
- The smallest and simplest are insertion sequences, or IS elements, which are 1–3 kb in length and encode the transposase protein required for transposition and one or more additional proteins that regulate the rate of transposition

Transposable Elements

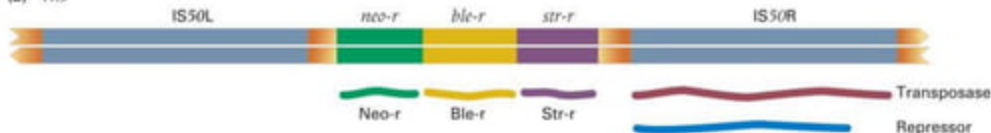
- Other transposable elements in bacteria contain one or more genes unrelated to transposition that can be mobilized along with the transposable element; this type of element is called a transposon
- Transposons can insert into plasmids which can be transferred to recipient cells by conjugation

Transposable elements are flanked by inverted repeats and often contain multiple antibiotic resistance genes

(A) IS50



(B) Tn5



- Integrons are DNA elements that encode a site-specific recombinase as well as a recognition region that allows other sequences with similar recognition regions to be incorporated into the integron by recombination.
- The elements that integrons acquire are known as cassettes
- Integron may acquire multiple-antibiotic-resistance cassettes, which results in the plasmid resistant to a large number of completely unrelated antibiotics
- Bacteria with resistance to multiple antibiotics are an increasing problem in public health

Integrons

